N. H.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum*, *Præfatio*.

VOLUME THE TWENTY-NINTH.

1873.

PART THE FIRST.
PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

LONDON:

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SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MDCCCLXXIII.

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Elected February 21, 1873.

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EXPLANATION OF THE PLATES.

ERRATA CORRIGENDA ET ADDENDA.

Page xxxvii, last line, *for* "hem" *read* "them."
Plate VII. Doubtful faults are shown thus – – – –.
Table facing p. 42, last line of column 2, *for* "ironstones" *read* "hornstones."
Page 222, last line, *for* "sles" *read* "isles."
  ,, 226, line 21, *for* "the object" *read* "one object which."
  ,, 235, line 34, *for* "Pl. IX. fig. 3" *read* "Pl. X. fig. 1."
  ,, 254, line 14 from bottom, for "*Rhynchonella crucis*" read "*Rhynchonella Crossii.*"
  ,, 256, note, *for* "Pl. X. fig. 2" *read* "Pl. X. fig. 1."
  ,, 264, line 6, *for* "spines" *read* "spires."
  ,, 271, line 6 from bottom, *for* "poltids" *read* "potlids."
  ,, 282, line 8 from bottom, *for* "Physical Geology" *read* "Stratigraphical Geology."
  ,, 300, line 14, *for* "ahd" *read* "and."
Plate XI. The *pink* patch at the southern extremity of the island of Raasay should be *dark red*, representing "felstone" instead of "trap."
Page 441, Title of paper *dele* "LL.D."
  ,, 530, line 8, *for* "5th" *read* "1st."
  ,, 532, line 7 from bottom, *for* "Galway" *read* "Antrim."

Note to Mr. Sharp's *paper on* "*The Oolites of Northamptonshire,*" p. 285.

[Dr. Lycett has been good enough to point out to me that *Am. terebratus*, Phil., occurs *not* in the Grey Limestone of Scarborough (as stated, page 285), but in the Cornbrash of both Yorkshire and the South-west of England. The presence, however, of *Alaria Phillipsii*, d'Orb., *Natica adducta*, Phil., *Trochus monilitectus*, Phil., *Gervillia acuta*, Sow., *Hinnites abjectus*, Phil., sp., *Lucina despecta*, Phil., *Rhynchonella spinosa*, Schloth., sp., and other forms, both in the Grey Limestone of Scarborough and in the Lincolnshire Limestone, sufficiently attests the affinity of the two formations. The assignment of *A. terebratus* to the Grey Limestone was not made by me, but probably arose from a misplaced specimen, a mistake likely to be occasioned by the similarity of the matrices, and affording another instance of the danger of relying upon the mineral conditions of a specimen in determining the identity of the bed from which it has been obtained.—S. S.]

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PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

November 6, 1872.

Lieut. Douglas A. Scott, R.E., 8 Chandos Street, Cavendish Square, W.; and Dr. J. Dormer Steele, Principal of Elmira Free Academy, Elmira, New York, were elected Fellows of the Society.

The following communications were read:—

1. *A* Report *on the* Tin Discoveries *in* Queensland. By T. F. Gregory, Esq.

(Communicated by the Right Hon. the Earl of Kimberley, H.M. Secretary of State for the Colonies).

Mineral Lands' Office, Stanthorpe,
2nd July, 1872.

Sir,—In pursuance of the instructions conveyed in your memorandum dated 18th ult., I have the honour to furnish, for the information of His Excellency the Governor, a Report on the Tin-fields at the head of the Severn river, in the district of Darling Downs, South.

The general geographical area of the stanniferous country within the Colony of Queensland, so far as is at present known, appears to be comprised within the following limits. Commencing on the main dividing range between the eastern and western waters at Lucky Valley Goldfields, near the head of the Condamine river, the northern boundary extends in a west-south-westerly direction for about twenty-five miles, passing fifteen miles south of the town of Warwick to the head of Pike's Creek, on the Pikedale Run;

from this point it is bounded by a slightly curved line extending south about twenty miles to the Severn river, three miles below the Ballandean Head Station, where it trends south-east for twelve miles further, meeting the boundary of New South Wales at the Tenterfield Run; thence the crest of the watershed which forms the boundary between the two Colonies embraces it in a north-easterly and easterly direction back to Lucky Valley, the area comprised being in round numbers five hundred and fifty square miles in extent. Of this area, however, only about two hundred and twenty-five square miles have hitherto been found sufficiently rich in tin-ore to pay for working; and consequently it is to this latter portion that my attention has been especially directed, although there are several instances of tin being found in payable quantities beyond these limits.

The physical and geological character of nearly the whole of the area described is that of an elevated granitic tableland intersected by ranges of abrupt hills, the highest limits of which are about three thousand feet above the sea, its eastern escarpment forming the watershed of the Clarence river, the northern that of the Condamine, and the south-western that of the Severn and McIntyre rivers.

The passes and gorges whence these rivers issue from the elevated granite country are mostly very steep and rugged, and difficult to traverse, especially to the north and eastward.

Of the rivers and watercourses which intersect this tract of country it will be only necessary, for present purposes, to refer to the Severn and its tributaries, as it is on them that by far the greater portion of mineral wealth is found.

The principal head of the Severn is the stream known as Quartpot Creek, which, with its numerous tributaries the Funker's Gap Creek, Four-mile, Law's, Ten-mile, Sugar-loaf, and Thirteen-mile Creeks, drain the eastern portion of the district, comprising fully one half of the country at present occupied by selections; while the northern head of the Severn, better known as the Broadwater, has for its tributaries Spring Creek, Reeves Gully, Hardy's and Cannon Creeks.

Again, to the westward, several watercourses known as the Ten-, Thirteen-, Fifteen-, and Twenty-mile branches of Pike's Creek flow westerly into a metamorphic formation in about seven or eight miles, where the tin-bearing country terminates. The majority of these watercourses rise in open sandy or rocky hollows, or shallow valleys, having at their commencement very little fall in them, and in ordinary seasons are well supplied with water, several being all but permanent streams, the main channels containing numerous large pools and sheets of water, in some instances over a quarter of a mile in length.

The fall of the country from their sources to Ballandean Head Station, an average distance of twenty miles, may be roughly estimated at from 400 to 600 feet, and in a few instances fully 1000.

The portion of the district over which the principal deposits of

tin-ore are distributed is that comprised by the watershed of the Severn river down to Ballandean Station, with the exception of about six miles of the extreme southern head of Quart-pot Creek and Accommodation Creek, both of which have hitherto not been found to yield payable ore.

The richest deposits have been found in the stream-beds and fluviatile flats on their banks, the payable ground varying from a few yards to 5 chains in width, occasionally broken by rocky bars; but even in these instances large deposits are frequently lodged in the pockets and crevices between the granite boulders. The aggregate length of these alluvial bands may be taken as about one hundred and forty miles on the Severn waters, with about thirty more on the tributaries to Pike's Creek.

A very careful inquiry and personal examination of a number of the various workings that have been commenced within the last few weeks establish very fair data upon which to estimate the probable yield of ore. This may now, with a tolerable degree of certainty, be stated at an average of ten tons per linear chain of the Creek beds. In some instances it has been found to extend to thirty tons per chain; but allowing for frequent interruptions by rocky bars, it will be safer to adopt the first-mentioned yield as a fair standard upon which to base an estimate of the amount of mineral that it is probable will be raised within the next few years from alluvial working alone.

Of the stanniferous lodes or veins it is impossible at present to speak with any degree of certainty; the two principal ones as yet discovered are near Ballandean Head Station, and at an outlying reef of red granite rising up in the midst of metamorphic slates and sandstone at a spot known as the "Red Rock," and situated about six miles apart in a north and south direction; the other crosses the Severn several times at the point where the tin was first discovered and the land selected by Messrs. Greenup and others.

These lodes or veins have as yet been but very partially tested; it would therefore be premature to give any decided opinion on them; they may, however, prove the source of an amount of wealth the production of which would extend over many years.

There are also a number of smaller lodes or veins, some of which I have not been able personally to inspect; the most promising appear to be on Law's Gully, on the claims of the Blue-Mountain Mining Company, as well as on Quart-pot and Sugar-loaf Creeks: they run in parallel lines bearing about north 50° east, commencing from near the boundary of New South Wales opposite the Ruby-Creek digging in that colony, and again near the Broadwater at a spot about a mile south-east from the junction of Hardy's Gully. This lode can be traced with interruptions all the way to the head of Spring Creek, a distance of nine or ten miles.

In describing the mineralogical character of the rocks generally, I cannot do better justice to the subject than by quoting from some valuable notes kindly furnished me by our well-known and talented geologist, Mr. D'Oyley Aplin, whose views on this subject coincide

with my own observations. He says, "I have met with no other description of tin-ore than the peroxide (cassiterite), even in specimens from veins. The ore, so far as I have seen it, is associated with granite only, which is invariably red; *i. e.* the felspar is a pink or red orthoclase, and the mica is generally black; but when crystals of tin-ore are found *in situ* the mica is white.

"The granite generally is coarse-grained and seems to disintegrate readily under atmospheric influence. There are numerous bands of loosely aggregated rock, granitoid in character, highly micaceous and traversed by bands and veins of quartz in all directions; in these bands crystals of tin-ore are abundant, and they (the bands) seem to have constituted local feeders along the courses of drainage.

"The crystals of tin-ore are generally found imbedded in and along the margin of the quartz threads or veins in those bands. In some instances they are imbedded in the micaceous portions only; and the mica is invariably white in those instances in the bands referred to. The strike of the bands and the distinct quartz veins in the granite is generally north-east and south-west.

"Along the western margin of the granite a broad belt of metamorphic rocks (slates and sandstones) extends on both banks of the Severn, constituting a series of rugged broken hills and ranges, in parts difficult to traverse except on foot; this tract of country stretches from five to six miles west of Ballandean to Maidenhead on the Severn, where the granite again appears and also the tin-ore.

"No tin floors, as at the Elsmore mine, in New South Wales, have been discovered."

The extent of mineral country applied for up to the present time is as follows:—

Number of selections 850.

Aggregate area about 74,000 acres.

Of these, judging from those already dealt with, it is probable about one third will be rejected as being land previously applied for or overlapping, leaving about 46,000 acres, for which permissive licenses will be issued, nearly the whole of which have been selected with frontages to the watercourses.

Although selections still continue at the rate of fifty portions per week, this cannot be maintained for more than six or eight weeks longer without the discovery of deposits in new localities hitherto unexplored, or lodes that may be found to exist on the tableland, as nearly the entire length of the watercourses is already selected.

The population at present located on the tin-fields may be set down as, at the least, 1200, while it is more likely to amount to 1500, the principal centre of occupation being the now rapidly rising private township of Stannum, the protracted delay in the sale of the government allotments in the township of Stanthorpe being the only reason why this town has not already doubled the number of inhabitants that are at present located on the private

lands adjoining, as the majority of persons prefer purchasing government building-lots to obtaining only leaseholds on the private townships.

In addition to the town reserve of Stanthorpe, it will very shortly be necessary to lay out another reserve on the Severn river, about fifteen miles lower down, somewhere in the vicinity of Accommodation Creek. This will be more especially required in the event of the lodes in that locality proving equal to the anticipations of the proprietors, as the working requisite to develop them properly will give employment to a large population.

It is not easy at present to form any very accurate estimate as to the number of persons that will be required within the next twelve months to enable selectors to fulfil the conditions required by the clause of the Act under which the Mineral lands have been acquired; but it is scarcely possible that they can be complied with unless, at the lowest computation, 5000 persons are employed, which number, allowing a fair proportion for persons engaged in other callings, including females and children &c., would not give more than three persons to each forty acres.

In reference to the probable time that will be required to work out the known beds of alluvial tin-ore, it must necessarily depend upon the number of persons engaged in it and the nature of the seasons; but under any probable conditions it is not likely that they will be so far worked out within the next three years as to occasion any diminution of the population below from 5000 to 8000; and the development of workable lodes would, from necessity, permanently establish a much larger population.

I have &c.,

(Signed) T. F. GREGORY,

Mineral Land Commissioner.

The Hon. The Secretary for Public Lands.

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2. Observations *on some of the* Recent Tin-ore Discoveries *in* New England, New South Wales. By G. H. F. Ulrich, Esq., F.G.S.

The discovery of tin-ore (cassiterite) in the province of New England, New South Wales, was brought under the Society's notice by a letter from Mr. G. Milner Stephen, F.G.S., of Sydney, read at the December meeting, 1871*; and finding from the discussion thereon, that the subject is not without interest to the Society, I beg to offer the following further observations made during a recent visit to that stanniferous country.

The district to which these remarks refer forms, as as it were, a hilly high plateau of the Australian Alps, of which Mount Ben Lomond represents here the highest point, with an elevation of nearly 4000 ft. above the sea-level. According to my observation, the pre-

* See Quart. Journ. Geol. Soc. vol. xxviii. p. 43.

dominant rocks are granite and basalt, enclosing subordinate areas composed of metamorphic slate and sandstone, which latter show in places intrusions of greenstone of very limited extent. The basalt has mostly broken through the highest crests and points of the ranges and spread in extensive streams, the surface of which is now more or less decomposed, over the country at the foot. Thus we see fine valleys, with fertile basaltic soils several feet in depth, bounded by well-wooded granite ranges, not perhaps exceeding 300 ft. in height, a beautiful park-like country, well watered by extensive creeks and small rivers, and with a climate similar to that of Central Europe; for the summer temperature rarely exceeds 80° F. in the shade, whilst during the winter months, June and July, there is frequently snow and ice.

Perhaps the richest mining-area as yet discovered is that of the Elsmore Company, situated about 12 miles east of the township of Inverell. It lies on the north-western side of the Macintyre river, and includes a granite range about 250 ft. in height and nearly 2 miles in length, dipping on all sides save that towards the river, beyond which the rock extends a considerable distance beneath basalt. The granite is micaceous and rendered porphyritic by crystals of white orthoclase, which frequently reach several inches in size; bluish grey oligoclase is also, though sparingly, associated. It is traversed by quartz veins several inches to above a foot in thickness, which contain cassiterite in fine druses, seams, and solitary crystals. Portions of these veins are highly micaceous, and represent in fact the rock called "Greisen" characteristic of the tin-ore-districts of Saxony and Bohemia *. Of far greater importance, however, than these veins are dykes of a softer kind of granite, which consists perhaps for 75 per cent. of its mass of small scaly greenish mica, and the remainder of felspar, quartz being but very rarely observable. Through these micaceous dykes cassiterite is not only well distributed in implanted crystals from the size of a pin's head to above that of a pea, but it occurs also in irregular veins of several inches thickness, and in nests and branches yielding lumps of nearly pure ore up to above 50 lbs. in weight. Part of the mass of one of these dykes forms a regular breccia of mica and imperfectly crystallized tin-ore cemented by hydrous oxide of iron.

The actual number of such dykes traversing the granite range is not known as yet: I saw six of them, each several feet in thickness; but there can be no doubt that more will be found when the ground is more minutely prospected than has hitherto been the case. It would astonish any European tin-miner walking over the range, to find along the outcrops of these dykes large blocks of the micaceous granite studded with moss- and lichen-covered druses of large crystals of cassiterite, or frequently to pick up weathered pieces of pure tin-ore several pounds in weight. After seeing the place and being informed that throughout the large area belonging to other Mining

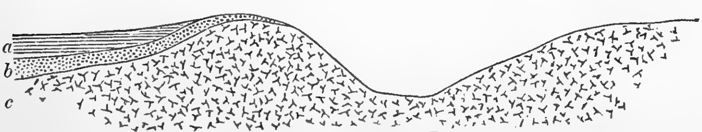
* In the tin-ore localities of the Beechworth gold-field, Victoria, this rock occurs also in a similar manner; but the surrounding granite is there very fine-grained and highly felspathic (euritic) and rarely shows porphyritic texture.

Companies on the opposite side of the river similar stanniferous quartz-veins and dykes had been discovered, the conclusion I came to is, that the granite mass, as a whole, represents one of the so-called "Stocks" or "Stockworks" similar to those of Saxony and Bohemia, but of incomparably greater size and richness.

As far as could be seen in the small workings of the Elsmore Company on several of the quartz-veins and dykes, the dip of the latter is rather steep, and the walls pretty well defined, but thickness irregular; thin flat veins join in occasionally. The deepest shaft sunk on one of the quartz-veins was about 60 ft.; and the tin-ore occurred in irregular thin veins, and often beautifully crystallized in druse-cavities. On examining the spoil-heap round this shaft, I discovered lumps of a ferruginous clayey substance full of thin light-green and yellow hexagonal prisms of beryl, associated with larger quartz-crystals. I also observed beryl on crystallized cassiterite specimens, its fragile prisms, generally not thicker than a stout pin, and up to an inch in length, interlaced between the tin-ore crystals. Of other minerals, I found in the stuff excavated from one of the dykes frequently patches of arsenical pyrites, and more rarely grains of copper pyrites, the former generally containing imbedded crystals of tin-ore. From another part of the ground the manager preserved a large piece of fine rock-crystal, which also enclosed small crystals of the ore. Wolfram has been found at several places forming nests in the granite, but not in association with cassiterite. Touching the latter itself, it is mostly of a pitch-black colour, occasionally translucent brown and hyacinth-red, and from some places greenish with a very pretty play of rays of red and yellow colour through it. Its crystalline form is rather simple as regards pyramidal planes; the prism is generally, however, highly modified. Twins like those from the Schlaggenwald mines are very abundant; and crystals perfectly developed all round, both twins and simple ones, the latter with twelve-sided prism and one pyramid, are not rare amongst the ore washed from the drift.

As regards the drift, it is very rich, and consists of recent granite detritus, from 6 in. to 2 ft. thick, spread all over the range, and of an older, probably Pliocene Tertiary cemented gravel of several feet thickness and mainly composed of waterworn pebbles and boulders of quartz (frequently rock-crystal and cairngorm), hard granite and hornstone, capping the top of the range, and dipping most likely, analogous to the older gold-drifts at other places, beneath the basalt adjoining (see sketch section, fig. 1).

Fig. 1.—*Sketch section across the bed of the Macintyre River.*



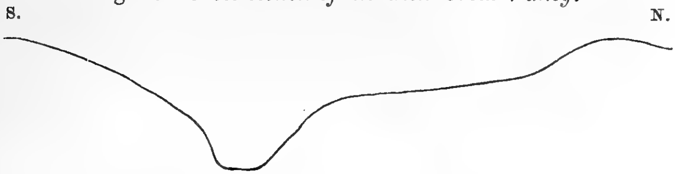
a. Basalt. *b.* Older Drift. *c.* Granite.

The tin-dish prospects of granite detritus I saw washed from a number of places gave per dish (about 20 lbs. weight) from 3 ounces to above 2 lbs. weight of ore, composed of but very slightly abraded, more or less perfect crystals and crystalline particles, from the size of a mustard seed to that of a small hazel-nut. Along a large ditch cut for the purpose of ground-sluicing, the black tin-crystals could easily be seen in the detritus on either side. The older drift contains tin-ore of generally finer grain, and much waterworn throughout, but is rather poor to within about 1 foot of the granite bottom. This bottom layer, however, is very rich in places, regular black seams of the ore being there observable, and some tin-dish prospects having yielded up to 6 lbs. weight of it.

On the north side of the range, not far from the basalt boundary, lies a deserted saw-pit many years old, in the stuff excavated from which rather coarse tin-ore particles were exposed in abundance after the first rain, but attracted not the slightest notice, as their nature was unknown. Mr. D. Brown, of Sydney, an enterprising mining prospector, claims to have been the first who recognized the ore, during one of his prospecting trips; he, with others, took up the land under lease from the Government; and it has since become the property of the present Elsmore tin-mining Company, who, however, are rather tardy in their operations to reap the valuable mineral harvest so profusely displayed over the field. Although nearly a year in existence, very little work has as yet been done on the lodes; and in order to wash the drift, the erection of a powerful engine with force-pump attached, for forcing the water from the river into a reservoir constructed on the top of the range, is only nearing its completion. The publicity given to the tin-ore discovery by the formation of the Company had the effect of leading to energetic prospecting not only in the immediate neighbourhood of the Elsmore ground, but, as success followed success, further and further away from it; and at the present moment it may be said that for perhaps 150 miles along the dividing range, far into Queensland, all the principal creeks and their branches, rising in or traversing granite-country, have been proved to be more or less richly stanniferous, whilst a number of rich veins of the ore have been found in the bounding ranges of several.

One of these more recent discoveries which I inspected is at the Glen Creek, about 40 miles northward of the Elsmore mine. The tin-bearing ground commences here at a point where the Glen Creek, which rises in high basaltic tableland, begins forcing its way for about 20 miles through a belt of granite and metamorphic-schist ranges, its tortuous course presenting a narrow, precipitous, in places gorge-like valley; hence its name. Both the beds and tributaries, and the surface-detritus of the bounding ranges contain tin-ore in variable quantities, all the way down the glen; but one of the richer localities (to which these remarks more especially refer) lies about 8 miles from the point of commencement. Here for about $1\frac{1}{2}$ mile along the course of the creek (E. and W.), the cross section of the valley is as given in the sketch (fig. 2):—

Fig. 2.—*Cross section of the Glen-Creek Valley.*



i. e. on the south side the range rises nearly vertically for above 100 ft. and from there pretty steeply towards the summit, whilst on the north there is also first a steep ascent of about 150 feet; but from there the rise is very gentle for nearly a mile up to the top of the range, the whole presenting a kind of small plateau intersected by shallow gullies, with low flat ridges intervening. The creek runs, except for about 10 chains, through metamorphic rock, a black, hard, flinty slate, without any trace of fossils; along the 10 chains its bed consists of a highly felspathic rather fine-grained and hard granite *, which is traversed by numerous veins of arsenical and copper pyrites, from $\frac{1}{4}$ to 6 inches in thickness, enclosing scattered crystals of tin-ore; but only one solid vein of the latter, about $\frac{3}{4}$ of an inch thick, has as yet been discovered, the wild and rocky nature of the glen at this place rendering minute prospecting very difficult.

The granite, as mentioned, is only exposed right in the bed of the creek, the precipitous slopes on both sides consisting of the black metamorphic slate, the line of contact of the two rocks being clearly visible and presenting no sudden change, but a more or less gradual transformation of one rock into the other. The before-mentioned ore-veins run from the granite into the slate, without any interruption or change. The sand and shingle, forming some narrow banks and filling large holes in the creek-bed, have not been properly tested as yet, but will no doubt prove very remunerative by sluicing: a few tin dishes full of the stuff from near the top of one of the banks produced each from one to two ounces of rather small-grained and much waterworn tin-ore. On the southern steep bounding range of the creek the surface detritus is very thin, and contains but little tin-ore; but the low hills on the above-mentioned plateau on the north side are covered with it from 6 inches to above $1\frac{1}{2}$ ft. deep, whilst the small gullies are filled with alluvial drift composed of sandy clay and gravel, from $1\frac{1}{2}$ to 4 ft. in thickness. Touching the tin-bearing qualities of the detritus, I saw about fifteen tin-dish prospects picked at random off the surface from as many different parts of the area; and these yielded, on being washed, from $\frac{1}{2}$ oz. up to 6 oz. of fine quality tin-ore per dish, the grains varying from the size of a pin's head to that of a pea, and being more or less crystalline and little waterworn. Two prospects of the bottom stuff of two holes sunk in two of the gullies gave each above 2 lbs. weight of generally coarser and more waterworn ore per dish.

* This rock shows a striking resemblance to the tin-granite of Beechworth Victoria, noticed in a previous foot-note.

The underlying rock of the principal part of the area consists of the black flinty metamorphic slate before noticed; but dispersed through it are several small outcrops of a rather coarse-grained micaceous granite enclosing large radiating patches of "schorl;" and close to one of these granite protrusions several veins of solid tin-ore, from 1 to 4 inches thick, have been found traversing the slate rock. These veins lie about ½ mile away from the granite exposed in the creek. The ore broken from these is, if any thing, of a more solid character than the vein-ore of the Elsmore mine, druse-cavities being apparently very rare or quite absent. That these veins contributed by their denudation largely to the tin-ore distributed through the surface detritus and alluvial drift near and below their line, there can be no doubt; but taking into account that both the latter are rich in tin-ore a considerable distance higher up the hilly plateau, and that specimens of quartz with crystallized tin-ore attached have been found there, it is not less certain that such ore and specimens must have been derived from other tin-ore veins traversing the slate, or perhaps a peculiar rock which occurs in large dykes and patches here and there over the area. This rock represents an extremely hard and tough greenstone diabase, the augitic constituent of which has the cleavage and lustre of diallage. I did not myself see specimens; but a miner in charge of the ground averred that he had found pieces of the rock traversed by thin veins of tin-ore. Its contact, or mode of connexion with the granite, could not be observed anywhere, the nearest protrusions of the latter lying perhaps 6 chains off. However, as the granite, judging from its scattered outcrops at the place and its massive occurrence about half a mile northward, doubtless underlies the country all round, it is most likely that the greenstone, as the younger of the two, has broken through it. A peculiarity of the latter is, that it weathers black or brownish black, and is far harder and tougher where exposed at the surface than underneath a covering of detritus or alluvial drift. At places where it is strongly affected by decomposition, as, for instance, in some of the holes sunk in the small gullies, in which it forms the bottom, it much resembles certain varieties of Serpentine.

The washing on a large scale of the stanniferous detritus and alluvial drift of the area under notice can most profitably be executed only by ground-sluicing; but the conducting of the water by means of races to the place, or forcing it from the creek for a distance of about a mile to the top of the range, a height of nearly 300 ft., will be rather expensive and difficult; still the richness and extent of the ground would warrant the undertaking.

Positive want of water or too great an expense attached to the bringing of it to the stanniferous localities will, however, I am afraid, be prohibitory of the working of a great number of those recently discovered. Still the produce of such as can be worked* will doubtless in no long time sensibly affect the tin-markets of the world: in fact it seems not unlikely that the production of tin-

* The Quart-pot Creek, in Queensland, will, it is supposed, alone yield from 4 to 500 tons of ore per week.

ore at this part of Australia will reach, if not surpass, that of all the old tin-mining countries combined.

Discussion.

Mr. Daintree commented on the enormous value of the 170 miles of frontage for stream-tin works exposed in Queensland. The value of these alone would, according to Mr. Gregory's calculation, be some £13,000,000; taking an equal value for those of New South Wales, there would be lying on the surface something like twenty-five times the whole amount of tin annually produced in Cornwall. In addition to this, there were lodes of immense length and richness. At the same time large tracts of similar granite to that containing the stanniferous veins were still unexplored in other parts of Queensland. What amount also of tin-bearing drift might exist under the tracts of basalt was still unascertained. The tin and other minerals were, he observed, limited to the palæozoic and metamorphic districts traversed by dykes, such as those mentioned in Mr. Ulrich's paper; and although very large areas of granite similar to that of the Severn river were to be found in other parts of Queensland and Australia, the stanniferous portions would be confined to the areas traversed by such dykes.

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3. *On the* Included Rock-fragments *of the* Cambridge Upper Greensand. By W. Johnson Sollas, Esq., and A. J. Jukes-Browne, Esq.

(Communicated by Prof. Ramsay, F.R.S., F.G.S.)

[Abridged.]

From time to time fragments of various rocks have been noticed in the formation of such size and angularity as to have suggested the idea to two preceding observers (Mr. Bonney and Mr. Seeley) that they might have been brought to their present position by the agency of ice. While ignorant of the suggestions of these gentlemen, we were forced independently to the same conclusion, and commenced, together, an examination of the subject. Our first step was to make an examination of all the erratics from the formation which had been preserved in the various local collections. The following is a descriptive list of the most important of these fragments.

Descriptive List of Rock-fragments.

No. 1. A large cuboidal block of coarse yellowish felspathic grit, very hard and compact, measuring $10 \times 7 \times 7$ inches, subangular, not much decomposed; incrusted with coprolite, *Exogyra*, *Spondylus truncatulus*, *Plicatula sigillum*, and *Ostrea vesiculosa*. *Derived* probably from the Millstone-grit of the north of England. *Collection*, Woodwardian Museum, signified after this by the initials W. M.

No. 2. A very angular, roughly rhombohedral prism of purplish-red indurated shale, moderately hard, measuring $9 \times 5 \times 5$, not

much water-worn or decomposed; incrusted with coprolite and *P. sigillum*. *Derived* probably from Old Red Sandstone of Scotland. *Collection* W. M.; in Mr. Browne's collection is a smaller piece.

No. 3. A larg subangular block of soft friable grey sandstone, measuring $14 \times 12 \times 6$ inches; rather rounded and water-worn; incrusted with coprolite, *P. sigillum*, and *Ostrea*; probably of Carboniferous origin. *Collection* W. J. Sollas.

No. 4. A subangular block of a fine conglomerate, consisting of small stones set in a purple quartzose matrix, measuring $6 \times 4 \times 3\frac{1}{2}$ inches, much rounded and water-worn; incrusted with coprolite, *P. sigillum*, and *Ostrea*. Resembles closely some of the Old Red conglomerates near their junction with the Silurian strata in Scotland. *Collection* A. J. Browne.

No. 5. A long square prism of black compact limestone, measuring $8 \times 4 \times 4$ inches, rather decomposed outside and pierced by a small boring animal; incrusted with coprolite, which penetrates all its cracks and hollows. Very similar in character to the Carboniferous black marbles. *Collection* W. M.

No. 6. An obtuse-angled prism of hard reddish sandstone, with included fragments of felspar, measuring $6 \times 8 \times 4$ inches; very angular, with sharp edges; incrusted with *Serpula*, *O. vesiculosa*, *P. sigillum*, and coprolite. *Collection* W. J. Sollas.

No. 7. An angular broken fragment of black basalt, with numerous crystals of olivine; in size $6 \times 5 \times 3$; rather decomposed on the outside and weathered white; resembles some of the olivine basalts on the east coast of Scotland. *Collection* W. J. Sollas. This stone has none of the characteristic Upper Greensand incrustations; it was obtained, however, with other stones which had, and the workmen declared they had all come from the "coprolite bed."

Besides the foregoing larger fragments, several smaller pieces are highly interesting:—

No. 8. A cuboidal subangular tablet of compact brown siliceous limestone, measuring $3 \times 3 \times 1\frac{1}{2}$ inches; smoothed, and abundantly scratched in various directions; incrusted with *P. sigillum* and *O. vesiculosa*. *Collection* W. M.

No. 9. A roundish granitic fragment, about $5 \times 4 \times 2$ inches; worn and decomposed, but showing on one side a flat surface with what seem to be traces of ice-polishing; incrusted with coprolite and *P. sigillum*. *Collection* W. M.

No. 10. A small flattish fragment of green sandy mica-schist, about $3\frac{1}{2} \times 2$ inches; smoothed on its flat faces and faintly striated; incrusted with coprolite and *P. sigillum*. *Collection* A. J. Browne.

No. 11. A rounded and water-worn fragment of tough decomposed green trap, about $4 \times 3 \times 2$; incrusted with *Ostrea* and *P. sigillum*, very similar to some of the green traps on the east coast of Scotland, for example those of Fife.

No. 12. A small broken fragment of granite composed of felspar, black mica, masses of fibrous hornblende, and irregular crystals of quartz, much decomposed. *Collection* W. M.

Fragments of gneiss, mica and hornblende schists, talcose

schists, granites, vein-quartz, grits, quartzites, and slates are very numerous.

We may form the following generalizations from the characters which these stones present.

I. Most of them are subangular, and many are extremely friable. The presence of these latter rocks is remarkable; fragments of soft sandstone (No. 3, for example), of various shales and talcose schists, are frequently met with, which could never have borne even a brief journey by water along the ocean-bed.

II. Many of them are of large size, especially as compared with the fine silt in which they were imbedded, the larger ones measuring more than a cubic foot. It is obviously impossible that any ordinary marine current could have moved along such blocks as these, especially from such great distances as we shall show they have probably come.

III. They are of very various lithological characters, and derived from several Palæozoic formations; among the most abundant are mica-schists, basalts, granites, felspathic shales, vein-quartz, and coarse grits; and we may refer them to gneissic, schistose, volcanic, and sedimentary rocks, probably of Silurian, Old-Red-Sandstone, and Carboniferous age. Such strata are not found anywhere *in situ* in the neighbourhood; and we must go to a great distance before we find any at all corresponding to them, either to Scotland or to Wales. This consideration, that numerous rock-fragments, some of which are very friable, have been brought from various localities at great distances, and yet retain their angularity, seems to us almost sufficient evidence in itself for their transportation by ice. We dismiss, at once, all notion of the agency of trees; for it is scarcely conceivable that so many stones from so many different formations could have been repeatedly borne to sea by such exceptional means of transport. The majority of these erratics present no signs of ice-scratches; but when we reflect on the small proportion of ice-scratched stones in the moraine matter borne away by an ordinary iceberg, and on the small percentage of ice-scratched boulders in many deposits of recent glacial drift, we see nothing in this fact inconsistent with their glacial derivation, especially when we remember that many of our Upper Greensand boulders are composed of soft or decomposable rocks from which ice-marks, even if once existing, would probably have been erased by the subsequent action of water. We think, therefore, that even without any more positive evidence we should have in this assemblage of large rock-fragments, mostly subangular and derived from various and distant formations, great reason to attribute their occurrence in their present situation to the transporting power of ice. Some of the stones present a few scratches in different parts of their surface, which are difficult to account for, except by the agency of ice; and others have flat faces which look as if they had once been striated surfaces. The stone numbered 8, especially, which is preserved in the Woodwardian Museum, we find to be unmistakably scratched in various directions, the striæ

passing directly under the incrusting *Plicatula sigillum*, and therefore, evidently, produced before the growth of the shells. The stone is composed of a peculiarly hard and compact siliceous limestone; and the scratches do not run in one parallel direction across the fragment as in glacier-scratched stones, but are distributed in various groups of parallel lines all over the surface, and especially round the edges and corners. This fragment is a remarkable one; for while some of its striæ are evidently ice-scratches, the majority are of a very curious nature and uncertain origin.

It may be added that occasionally a large number of fragments are found associated in one spot; six large stones, of various constitution, were found huddled together at Waterbeach.

Having then arrived at the conclusion that the Upper Greensand erratics have been brought hither by floating ice, there next arises the question as to whence they have come; and we think, after considering all sides of the case, that the facts point unmistakably to Scotland and the North for an answer. Along the eastern coast of Scotland, in Aberdeen, Forfar, and Fife, we have successively granite, mica-schist, and basalt, Silurian, Old Red Sandstone and Carboniferous rocks; while in Fifeshire, Edinburgh, and Berwick there is a vast extension of volcanic rocks, from which the erratic trap, basalt, and obsidian of the Upper Greensand might have been derived. It is true that obsidian is not found in Scotland now; tachylite, however, occurs in small quantity on the Fifeshire coast; and we do not know what volcanic rocks may have existed along the extension eastwards of the Scottish coast towards Scandinavia. Some of the rocks are strikingly Norwegian in character, far more closely related to some of the hornblendic rocks of south Norway than to any in Scotland. In deciding thus on a northern origin for our erratics we are supported both by Mr. Bonney and Mr. Paley, who have given some attention to the question.

Mr. Bonney has shown that the Cambridge coprolites were originally formed in the topmost beds of the Gault, and that the denudation of these beds has given rise to the thin seam which bears the name of the Upper Greensand; and it therefore becomes a question as to when the included erratics were brought down, whether during the deposition of the Gault, or during its denudation and the formation of the Greensand. Since we know that the Gault clay was formed in a comparatively quiet sea, and that, after some thickness had been deposited, change of conditions and extensive denudation ensued, it is reasonable to attribute these occurrences in part to the cold current of which we have evidence in the Cambridge erratics. Some of the stones are covered by Gault coprolite, and hence must have fallen into the upper beds of the Gault, during the deposition of which cold conditions must have prevailed.

The fauna, consisting partly of Gault fossils and partly of true Upper Greensand forms, agrees very well with these conclusions. The marine fauna is an abundant one, being, as we should expect from the origin of the stratum, a mixture of deep-sea and littoral forms; but the shells are by no means large, nothing like the splendid

fossils, for instance, which characterize the Gault of Folkestone. The representative Cephalopoda seldom attain a large size; of Gasteropoda and Lamellibranchs such genera as *Rostellaria*, *Trochus*, *Natica*, *Avicula*, *Spondylus*, *Arca*, and *Pholadomya* are certainly dwarfed; while the small *Plicatulæ* and *Ostreæ*, which are known to be truly Upper Greensand fossils, are very diminutive indeed. *Terebratula* is fine and numerous; *Rhynchonella*, *Dentalium*, and *Nucula*, usually considered extra-tropical forms, are also numerous, the two former especially so; *Echinoderms* are rare, *Crustacea* not very common, and both are small, as also the coral *Smilotrochus* and the still more diminutive *Micrabacea*.

In the Greensand of the Isle of Wight the fauna is very different: Brachiopods are far less numerous, while Echinoderms and Cephalopoda become finer; *Cardium*, *Cucullæa*, *Gryphæa*, *Pectunculus*, *Thetis*, and *Trigonia* occur as new and seemingly more tropical forms. The Gault unfortunately is thin and unfossiliferous in this locality, so that we have not the opportunity of comparing the fossils of its upper layers with those of the Cambridge Greensand; but the fine Ammonites and Hamites of the Folkestone Gault are well known and bespeak a more favourable climate.

Supplementary Notes.

i. Since the reading of the above communication we have had the good fortune to find a block of massive Labradorite about a cubic foot in size and incrusted with coprolite; this would seem to be a Norwegian erratic.

ii. Mr. Seeley states that he has found the well-known concretions of the Magnesian Limestone in our formation; and since these concretionary forms are peculiar to the Magnesian Limestone of N. E. England, their occurrence strengthens our conclusions as to the northern derivation of the Cambridge erratics, as does also the occurrence of *Poteriocrinus*, likewise met with by Mr. Seeley.

iii. Since the boring at Kentish Town passed through 14 feet of Upper Greensand and 130 feet of Gault above Palæozoic rocks, the thicknesses being those of the southern area of the beds in question, while at Hitchin there is only 1 foot of Greensand and over 200 of Gault, and this Greensand is of the Cambridge coprolitic type, it is probable that these two different types of Greensand were deposited in different areas and separated by land now under the Hertford Downs. In this way we would explain the evidence of cold conditions in the Cambridge and Bedford area, while a comparatively warm sea existed over Southern England.

Discussion.

Mr. Seeley gave some history of the specimens in the Woodwardian Museum, on which the paper was partly founded, some of which had been collected by the late Mr. Lucas Barrett, and others by himself. He thought that some of the scratches on one of the specimens from Granchester might be of modern origin, and doubted

whether the place of derivation of most of the blocks was Scotland. Besides the rocks mentioned, he had found fragments of Magnesian Limestone and columns of *Poteriocrinus*. He could not agree with the authors as to the physical geography of Britain during the Upper-Greensand period. He considered that it was from the denudation of the great barrier mentioned in the paper that much of the material of the Upper Greensand was derived, and disputed the value of conclusions as to climate founded on so small an area of induction.

Mr. J. F. Walker did not agree with the authors as to the absence of large ammonites in the Cambridge Greensand, and of fossils in the Gault of the neighbourhood of Cambridge; the latter had been found by Mr. Keeping at Upware. He inquired in what state of combination the phosphoric acid was supposed to be brought from Scotland.

Mr. Sollas, in reply, stated that the scratches referred to by Mr. Seeley could not be of modern formation, since they were in many cases partly covered by incrusting *Plicatula sigillum*, and pointed out the difficulty attending the supposition that the blocks were derived from any other than a northern source. He thought that the large ammonites were derived from a lower bed in the Gault than that from which he had supposed a large portion of the Upper-Greensand fossils had been derived. He considered that the phosphoric acid had been conveyed along the sea-bottom in a cold current, perhaps as a calcic phosphate.

Mr. Jukes-Browne also replied, and drew attention to a section he had prepared, which showed that the London and Harwich anticlinal had been covered with a great thickness of Gault at the time of the deposit of the Upper Greensand.

Prof. Ramsay, in winding up the discussion, expressed an opinion that the forms of pebbles of glacial origin might be recognized by an experienced eye even though the striæ had been worn off, and that some of the pebbles exhibited showed traces of such an origin. He called attention to the fact that the deposit of glaciated pebbles in any particular locality did not in any way involve the existence of arctic conditions at that spot, though they might exist elsewhere.

November 20, 1872.

Lieut. Charles Cooper King, Royal Marine Artillery, Royal Military College, Sandhurst, and H. L. Florence, Esq., 16 Christchurch Road, Streatham Hill, were elected Fellows of the Society.

The following communications were read:—

1. *On the* Geology *of the* Thunder-Bay *and* Shabendowan Mining-districts *on the* North Shore *of* Lake Superior. By H. Alleyne Nicholson, M.D., D.Sc., M.A., F.G.S., F.R.S.E., &c., Professor of Natural History in University College, Toronto.

Having recently had an opportunity of accompanying an exploring party to the north of Lake Superior, I take this occasion to give a

brief geological account of the mining-districts of Thunder Bay and Shabendowan, both of which are likely to become ultimately of great importance. Though as yet very imperfectly explored, and still more imperfectly opened up and developed, the entire north shore of Lake Superior has already been shown to be intersected by numerous metalliferous veins, and promises to equal in richness the most celebrated mining-regions of the North American continent. At present, however, I shall confine my attention to the silver-bearing district of Thunder Bay, and the auriferous region which surrounds Lake Shabendowan.

Thunder Bay, Black Bay, and Neepigon Bay are three remarkable bays on the north shore of Lake Superior, almost shut off from the main lake by islands, and assuming more or less the character of independent lakes. The first of these is the most westerly, and is a beautiful sheet of water, about 28 miles in length and 12 miles across. On its northern shore are situated the settlements of Fort William and Prince Arthur's Landing, the former a Hudson's Bay port of comparative antiquity, the latter a newly established town, destined to be the centre of the silver-mining district. The chief river flowing into Thunder Bay is the Kaministiquia, a large and important stream, which drains a series of lakes lying to the north of Lake Superior, and which debouches into the latter at Fort William. The bay, as viewed from its northern shore, appears to be almost land-locked, and presents several features of striking interest, both from a geological and an artistic point of view. Facing Prince Arthur's Landing, to the south-east is the bold and bare prominence known as Thunder Cape, which is 1350 feet above the level of the lake, and more than 2000 feet above the level of the sea. The lower portion of this rugged elevation is formed of black argillaceous shales, whilst the higher portion is constituted by a vast tabular mass of columnar trap interstratified with the former. Both of these belong to what Canadian geologists term the "Copper-bearing Series," of which I shall have to speak again. The mouth of Thunder Bay is divided into two channels by several islands, the largest of which is Pie Island, which derives its somewhat unromantic name from the presence on its western end of a great rounded, flat-topped, pie-shaped mass of trap, forming a continuation of the great overflow of Thunder Cape. To the west, again, on the mainland, and beyond the mouth of the Kaministiquia river, the same trap is continued into a great series of rugged hills, of which the one known as "Mackay's Mountain" has an elevation of 800 feet above the level of Lake Superior.

The rocks which immediately surround Thunder Bay belong to the so-called "Lower" and "Upper Copper-bearing Series" of Canadian geologists. The relations which subsist between these two groups have not yet been satisfactorily determined; and the age of both is still a matter of opinion. The Upper Copper-bearing series consists essentially of red, white, and grey dolomitic sandstones, red sandstones and shales, reddish limestones, indurated red and yellowish marls, red sandstones and conglomerates, and inter-

stratified traps. These have generally been regarded as corresponding either to the Potsdam Sandstone (Upper Cambrian), or to some of the lowest members of the Lower Silurian; but Mr. Robert Bell, of the Geological Survey of Canada, has recently put forth the opinion that they are truly of Triassic or Permian age. In the absence of any satisfactory palæontological evidence, this question cannot be definitely settled; but the available stratigraphical evidence would rather support the view of Sir William Logan, that the Upper Copper-bearing series is of Lower Silurian age.

The Lower Copper-bearing series is well exposed on the north shore of Thunder Bay, extending beyond the limits of the bay as far westwards as the mouth of the Pigeon river. The series consists in ascending order of:—1. Green siliceous conglomerates containing pebbles of quartz, jasper, and slate; 2. Grey and black chert-bands, separated from one another by thin courses of dark grey dolomite; 3. Black shales and flags, with associated hornblendic traps; 4. Grey argillaceous sandstones and shales. No organic remains have hitherto been discovered in the Lower Copper-bearing rocks; and the age of the series is therefore uncertain. It is most probable, however, that the group should be referred to the base of the Lower Silurian series. The entire thickness of the Lower Copper-bearing rocks is probably about 1500 feet; and their general strike is from nearly E. and W. to nearly N.E. and S.W. The series is traversed by trap-dykes; and there are also several well-marked interstratified traps.

The Lower Copper-bearing series acquires a special interest from the fact that it is penetrated by two sets of mineral veins, which promise to become of great importance from the quantity of silver which they contain. The majority of the lodes run along the strike of the beds, having a general E.N.E. and W.S.W. direction; but there is also a set of transverse lodes, which have a direction more or less nearly north and south.

Of the north and south lodes, the most important is the now celebrated "Silver-Islet" vein, situated on an exceedingly small rocky islet immediately to the south of Thunder Cape. The vein has a width of from three to four feet, and the vein-stuff consists of quartz impregnated with native silver and galena. Picked specimens of the ore assay from £1000 to £2000 per ton; but this is, of course, exceptional. The mine has only been worked for about two years, but it has hitherto proved extraordinarily productive.

The most important of the second series of veins, namely those which run along the strike of the stratified rocks and have a general E. and W. direction, is the so-called "Shuniah vein." This large vein has been worked at several points along its course, and traverses the Lower Copper-bearing rocks of the north shore of Thunder Bay, running pretty nearly parallel to the shore, and at a distance from it of 1½ to 2 miles. None of the mines on this lode can be said to be as yet out of their infancy; but the results already obtained are such as to warrant very sanguine expectations. The Shuniah Mine itself is situated about 3½ miles to the N.E. of Prince

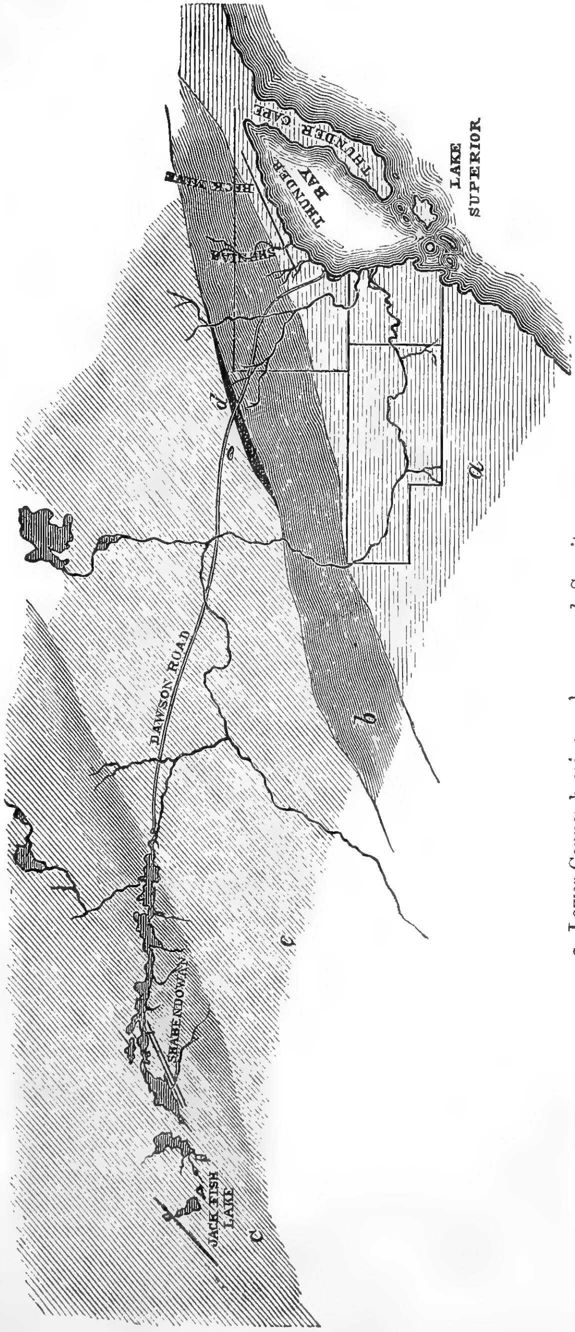

Fig. 1.—*Geological Sketch Map of the country from Thunder Bay to Lake Shabendowan and Jackfish Lake.*

a. Lower Copper-bearing rocks.
b. Laurentian rocks.
c. Huronian rocks.
d. Syenite.

Arthur's Landing. At this point the vein strikes nearly east and west, and is almost vertical. Its width is about 22 feet; and the vein-stuff consists mainly of calc spar. Quartz and fluor spar are of occasional occurrence; and there is a considerable quantity of iron pyrites. The silver is present both in the native form and as sulphide, some specimens being extremely rich. The vein cuts through hard black shales, but has a large mass of hornblendic trap about 50 feet to the south. The vein, however, does not run exactly along the strike of the beds, so that in following it to the west it comes ultimately to have the trap as its foot-wall. Like almost all the veins of the north shore of Lake Superior, the Shuniah lode is of a brecciated character, containing numerous fragments of the country rock. The Shuniah vein admits of being traced for several miles towards the east; and I entertain no doubt that the so-called 3 A and Beck mines are both situated upon this lode. In passing towards the east, however, the vein diminishes somewhat in thickness, and the vein-stuff becomes siliceous instead of being calcareous. At all points where the vein has been opened it has been found to contain silver, generally in the native form, associated with silver glance. At the 3 A location the vein also contains a considerable quantity of copper-nickel; and at the Beck or Silver Harbour Mine the silver is commonly associated with zinc-blende.

The gold-districts of Shabendowan, Round Lake, and Jackfish Lake are situated nearly to the west of Prince Arthur's Landing, the first of these being distant about 60 miles from Thunder Bay. Lake Shabendowan is reached by the so-called "Dawson Road," the commencement of the celebrated "Red-River route," the length of the road being about 47 miles. The entire district travelled over by the "Dawson Road," between Thunder Bay and the foot of Lake Shabendowan, is of an undulating character, numerous rugged bosses of rock everywhere protruding in ranges which have a prevailing N.E. and S.W. direction. Where not burnt, the country is covered with a dense timber; but the trees are of small size, totally unfit for "lumbering"-purposes. They consist mostly of spruce, tamarack, white birch, poplar, bastard pine, and pitch-pine; but the oak, white and red pine, and maple are altogether wanting. The fundamental rocks of the entire region everywhere exhibit unmistakable proofs of the passage over them of enormous masses of land-ice. Every rock-exposure is *moutonnée*, polished, and striated; and we must conclude that the former condition of the country was very similar to that now obtaining in Greenland. The general direction of the striæ is N. and S.; but there is a minor set of grooves occasionally visible, the direction of which is nearly east and west. The greater part of the country is thickly covered up with drift, containing numerous and often large boulders of syenite, granite, gneiss, greenstone, slate, &c., all of which appear to have travelled from the north towards the south. In some places also (as near the bridge over the Kaministiquia river) there are large masses of stratified drift.

Leaving Prince Arthur's Landing by the Dawson Road, we pass for the first three or four miles over the black shales and interstratified traps of the "Lower Copper-bearing series." Four or five miles to the north-east of Thunder Bay there comes on a range of syenitic and gneissic rocks of Laurentian age, as I should imagine by the interventions of an E. and W. dislocation; and these continue to be exposed for several miles. These in turn are succeeded to the N.W. by a vast series of rocks referable to the Huronian Group (see Map, fig. 1, and section, fig. 2). The first members of this series consist of greenish or grey slates, with bands of gneiss and occasional trap-dykes. At the Government post known as the "Fifteen-mile Shanty," and from here up to the foot of Lake Shabendowan, a distance of 32 miles, we cross a succession of bedded traps, mostly green in colour, interstratified with great masses of greenish, grey, or drab-coloured slate. The road runs a little to the north of west, and the general strike of the beds is W. by N. and E. by S.; so that the actual thickness of beds crossed over, though very considerable, is not so great as might at first sight appear to be the case. These Huronian slates and traps present a most singular resemblance to the green slates and porphyries of the Lake-district of the north of England. This likeness is shown in their mode of weathering, in the kind of scenery produced, and especially in the lithological character of the slates. The slates in question have a prevailing green colour, are usually fine-grained, but are not unfrequently brecciated, and are divided by a more or less nearly vertical cleavage, the direction of which is remarkably persistent over very large areas. The surfaces of the slate are not uncommonly glossy; and in some cases, at any rate, the cleavage appears to coincide with the bedding of the rock. These slates have been generally spoken of as "talcose" or "chloritic" slates; but I entertain no doubt that they are truly of the nature of bedded felspathic ashes. They do sometimes contain talc, and are occasionally serpentinous; but I am satisfied

Fig. 2.—*Sketch Section from Prince Arthur's Landing to the foot of Lake Shabendowan.—Distance 47 miles.*

a. Lower Copper-bearing rocks. *b.* Laurentian ridge. *c c.* Trappean Rocks of Huronian age. *d d.* Huronian slates. *e.* Syenite.

that this is the result of the metamorphic action to which the whole of the series has evidently been subjected.

At the foot of Lake Shabendowan, 47 miles from Prince Arthur's Landing, these Huronian slates are finely exposed in a series of low ranges, which run E. and W. along the strike of the beds, separated by little swampy valleys. All the tops of the ridges are *moutonnée* in the most magnificent manner, and are deeply scored with regular striæ having a southerly direction. At one point, about half a mile to the N.E. of the Government station, the slates come into contact with an intrusive trap of a highly crystalline character, consisting of a mass of crystals of dark green hornblende mixed with a little yellowish felspar. In the immediate vicinity of the trap the slates are greatly indurated, and have developed in them numerous spots of flesh-coloured felspar and small crystals of hornblende.

Lake Shabendowan is about 28 miles in length, with a width which, though variable, rarely exceeds 2 or 3 miles. Its general direction is E. and W., gradually trending round to the S.W. towards its head. The sides of the lake are for the most part exceedingly rugged and rocky, though the elevation of the hills and ridges is very trifling. The rocks are generally very thinly covered with soil; and the timber is small and worthless, at the same time that it is so dense as seriously to impede locomotion. Here, however, for the first time since leaving Prince Arthur's Landing, I noticed a few examples of the white pine. At various points along the margins of the lake are considerable deposits which, if not truly alluvial, are at any rate referable to the later portion of the glacial period. The deposits in question consist of coarse sand without boulders, but containing small rounded pebbles, and sometimes indistinctly stratified. The thickness of these sands is sometimes very considerable; and they contain a good deal of magnetic iron and a minute quantity of gold.

Leaving the foot of Shabendowan, we pass over a succession of trappean rocks, which continue without interruption to a point about 15 miles up the lake. Whether these traps are interstratified or intrusive I was unable to determine with certainty; but the occasional occurrence of thin courses of a slaty nature would lend support to the former view. Under any circumstances these rocks appear to be greatly metamorphosed, and in many places they become genuine syenites by the development in them of a sparing amount of quartz. These traps are likewise penetrated by a series of veins which run N.E. and S.W.; but the latter are of small size, and do not appear to contain any minerals of any value.

From a point about 15 miles from the foot of the lake up to its head, a distance of 13 miles, the entire country is occupied by Huronian slates, having a vertical cleavage and a strike which varies from E.N.E. and W.S.W. to N.E. and S.W., or E. by N. and W. by S. These slates have in many cases glossy surfaces and a soapy feel, apparently from the presence in them of a certain amount of talc, whilst they are sometimes so soft as to be scratched readily with the finger-nail. I am, however, of opinion that

these slates, like the similar rocks to the S.E. of Shabendowan, are truly of the nature of felspathic ashes, and that the talc has been developed in them as a secondary product. This view is further supported by the fact that the slates, where they have been directly metamorphosed (as by an intrusive trap), have developed in them numerous large crystals of felspar. The colour of the slates is uniformly greenish, and they present the most striking resemblance to the "green slates" of Cumberland and Westmoreland.

These Huronian slates extend for an unknown, but certainly considerable, distance to the N.W. of the head of Lake Shabendowan; and they are of special interest as containing numerous veins, some of which are of an auriferous character. A large number of veins has been already discovered, all of which have an E.N.E. and W.S.W. direction, conforming to the strike of the beds. The vein-stuff is uniformly quartz, containing copper pyrites; and free gold is rarely present. On the other hand, the gold appears to be contained in the copper pyrites, or it is disseminated through the quartz in particles too small to be detected by a hand-lens. The most important of the veins already discovered are the "Edgar and Gibbins" veins and the "McKellar" vein. The "Edgar and Gibbins" veins are exposed along the course of a stream known as the Kawashagamok or "clear-water" river, which flows into Lake Shabendowan from the S.E., about 2 miles below its head. Both veins have an E.N.E. and W.S.W. direction, and cut the Huronian slates vertically. The Edgar vein is about 4 feet wide, and consists of white compact quartz with a resinous fracture, exhibiting a very distinct arrangement in layers parallel to the walls of the vein. The vein-stuff contains an abundance of copper pyrites, which is doubtless auriferous; but free gold has not as yet been detected in it. The Gibbins vein appears to have a width of about 2 feet at the surface, and can be traced for nearly half a mile along the strike. The vein-stuff is quartz, singularly unlike the quartz of the Edgar vein in appearance, and of a most peculiar granular character. The minerals contained in this vein consist chiefly of copper pyrites, which is probably of an auriferous character. Free gold is also present in small quantity. Besides copper pyrites the vein further contains "embesite," or "horseflesh ore" (oxysulphuret of copper), coating the crystals of the former mineral. Lastly, iron pyrites is sparingly present; and there is a little carbonate of copper, consequent on the decomposition of the copper pyrites.

The McKellar vein is situated 13 miles to the west of Lake Shabendowan, and about half a mile to the west of Jackfish Lake. It is about 8 feet in width; and the gangue is quartz. The vein is richly metalliferous, containing an abundance of copper pyrites and galena, along with small quantities of native gold and native silver, iron pyrites, and sulphide of silver. The vein has been traced along the strike for about eight miles, maintaining a N.E. and S.W. direction, and it will no doubt prove ultimately to be a very valuable mineral property. In the meanwhile, however, in common with all the

other veins of this district, nothing more has been done to it than simply to prove its existence.

Discussion.

Mr. H. Woodward stated that Dr. Nicholson had presented to the British Museum some of the rich specimens of silver-ore mentioned in the paper.

Mr. D. Forbes corroborated the author as to the richness of the ore. A lump which had been submitted to him, weighing 295 lbs., contained no less than 187 lbs. of silver. He called attention to the resemblance between the vein-stuff from Thunder Bay and that from the Kongsberg silver mines of Norway, many specimens being so much alike that it was impossible to distinguish them.

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2. Note *on the* Relations *of the* Supposed Carboniferous Plants *of* Bear Island *with the* Palæozoic Flora *of* North America. By J. W. Dawson, LL.D., F.R.S., F.G.S., &c.

I have only recently received the May number of the 'Geological Journal,' containing the interesting paper of Dr. Heer on the plants above mentioned, and beg to request permission to address to the Society a few remarks on their supposed equivalency with the American Devonian Flora.

The plants catalogued by Dr. Heer, and characterizing what he calls the "Ursa Stage," are in part representatives of those of the American flora which I have described as the "Lower Carboniferous Coal-measures" (Subcarboniferous of Dana), and whose characteristic species, as developed in Nova Scotia, I noticed in the Journal of the Geological Society in 1858 (vol. xv.). Dr. Heer's list, however, includes some Upper Devonian forms; and I would suggest that either the plants of two distinct beds, one Lower Carboniferous and the other Upper Devonian, have been near to or in contact with each other and have been intermixed, or else that in this high northern latitude, in which (for reasons stated in my Report on the Devonian Flora *) I believe the Devonian plants to have originated, there was an actual intermixture of the two floras. In America, at the base of the Carboniferous of Ohio, a transition of this kind seems to occur; but elsewhere in North-Eastern America the Lower Carboniferous beds are usually unmixed with the Devonian.

Dr. Heer, however, proceeds to identify these plants with those of the American Chemung, and even with those of the Middle Devonian of New Brunswick, as described by me—a conclusion from which I must altogether dissent, inasmuch as the latter belong to beds which were disturbed and partially metamorphosed before the deposition of the lowest Carboniferous or "Subcarboniferous" beds.

Dr. Heer's error seems to have arisen from want of acquaintance with the rich flora of the middle Devonian, which, while differing in

* Geological Survey of Canada, 1871.

species, has much resemblance in its general facies, and especially in its richness in ferns, to that of the Coal-formation.

To geologists acquainted with the stratigraphy and the accompanying animal fossils, Dr. Heer's conclusions will of course appear untenable; but they may regard them as invalidating the evidence of fossil plants; and for this reason it is, I think, desirable to give publicity to the above statements.

I may add that, since the publication of my paper in 1858, much additional material from the Lower Carboniferous Coal-measures has come into my hands from Nova Scotia, New Brunswick, and Newfoundland, which may throw light on the corresponding floras of the more northern regions, and which I hope to publish in the form of a Report similar to that lately issued on the Devonian flora.

P.S.—I consider the British equivalent of the Lower Coal-measures of Eastern America to be the Lower Limestone Shales, the *Tuedian group* of Mr. Tate (1858), but which have recently been called the "Calciferous Sandstone" (a name preoccupied for a Cambrian group in America). This group does not constitute "beds of passage" to the Devonian, more especially in Eastern America, where the Lower Coal-formation rests unconformably on the Devonian, and is broadly distinguished by its fossils.

Discussion.

Mr. Carruthers stated that the list of the eleven Lower Carboniferous plants published in Principal Dawson's 'Acadian Geology' did not contain a single species found in Bear Island; but, on the other hand, some species and several well-marked forms were common to the Bear-Island deposits and the Devonians of North America, and he had no doubt that Prof. Heer had in his paper rightly correlated these floras. As to the age of these plant-bearing beds, found alike in Bear Island, Ireland, the Vosges Mountains, Canada, and Australia, Mr. Carruthers said that it was difficult to draw any lines which would separate the Palæozoic plants into clearly marked and distinct floras; but if the Devonian is to be retained as a system, all these plant-bearing beds belonged rather to that system than to the Carboniferous.

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3. Further Notes *on* Eocene Crustacea *from* Portsmouth. By Henry Woodward, Esq., F.G.S., F.Z.S., of the British Museum.

[Plates I. & II.]

On December 21st, 1870, I laid before this Society descriptions of three new forms of Crustacea, obtained by Messrs. C. J. A. Meyer and Caleb Evans, during the progress of the "Dockyard Extension Works" at Portsmouth, from strata of Lower Eocene age. Since that date, these ardent collectors have pursued their studies of the beds exposed, and continued to secure all the fossils within their reach. Through their kindness I have from time to time been enabled to

examine and study the additions made to the Crustacea from this rich locality, and I now beg leave to submit my further notes upon them to the Society.

On the first form (named by me, in my former paper, *Palæocorystes glabra*) I have no additional materials to present; but of the genus *Rhachiosoma* (represented at first by only *two* imperfectly preserved specimens, named respectively *R. bispinosa*, and *R. echinata*) there are now nine examples known.

The accession of these very perfect specimens, necessitates the redescription of *R. bispinosa*, for which there are now ample materials.

Four other specimens, representing two new Eocene forms, about to be described, and a large *Thenops*, near to *T. scyllariformis*, complete the series.

RHACHIOSOMA BISPINOSA, H. Woodw., 1870, Quart. Journ. Geol. Soc. 1871, vol. xxvii. pl. iv. fig. 3, p. 91. Pl. I.

Although originally supposed to be the smaller form, the discovery of several new specimens of this species shows it to have been fully as large as, or perhaps even larger than, *R. echinata*. It also proves that the remarkable development of the two lateral spines is a very persistent character in all the individuals; none of the new examples show a tendency to a *branched lateral spine*, like that seen in *R. echinata*, in which the spine appears also to be somewhat flattened, whereas in *R. bispinosa* it is nearly, if not quite, round in section. These spines have been erroneously spoken of in my former description as "hepatic;" they should more correctly have been styled "branchial" or "epibranchial" spines.

If we compare the figure of *R. bispinosa* accompanying the earlier description with those now presented (see Pl. I.), it will be seen that we are now made acquainted, not only with all the limbs (then only known from a single chela in *R. echinata*), but also with the frontal border of the carapace (so very important and characteristic a part), and with the underside (not visible in either of the first-found examples), revealing the abdomen of both the male and female, and the maxillipeds.

The hepatic border is armed with three prominent nearly equidistant spines, whilst a fourth forms the outer boundary of the orbital fossa. The frontal region displays a slight median depression, which may be traced as far back as to the centre of the gastric region, and is marked by a cleft in the rostrum, which thus presents three small, nearly equal serrations on either side, descending towards and forming the inner margin of the orbit.

The superior orbital border is marked by two equidistant fissures—a character, however, which is observable also in the *Canceridæ* and *Corystidæ*, as well as in *Portunidæ*, to which our genus *Rhachiosoma* undoubtedly belongs.

The marginal spines on the latero-anterior or hepatic border give to the front of the carapace a slightly sinuous or wavy surface, as do also the two great epibranchial spines, whilst the three tubercles, arranged in a line on either branchial region, contribute by their

tumid bases to relieve and diversify the surface of the carapace of this elegant crustacean.

Underside.—We have six specimens of *R. bispinosa*, which exhibit the underside in a more or less satisfactory manner. Of these, four are males, and two are females, the difference in sex being indicated, as in other Brachyures, by the disparity in the breadth of the abdominal somites (Pl. I. figs. 2, 3, 5, & 6).

The Branchiostegal Plate.—The suture formed by the union of the carapace with the branchiostegal plate is nearly parallel with the latero-anterior margin, it then turns almost at a right angle at the base of the great epibranchial spine; and the plate rapidly becomes narrower, ending at a point opposite that at which the limbs of the fourth pair take their rise. The inner margin is deeply excavated, to admit of the insertion of the legs along the margin of the plastro-sternal plates.

The Plastrosternum.—The five pairs of plates*, which are visible and which, soldered together, compose the plastrosternum, differ but slightly (save in their relative breadth) in the male and female, the deep median *sulcus* being narrower in the former (♂), and broader in the latter (♀), to admit the broader abdominal plates of the female. It closely agrees in form with that of other Portunidæ.

The Maxillipeds.—Three specimens of this crab show remains of the external jaw-feet, or maxillipeds, more or less perfect. The endopodite is broad, straight-sided, and divided by a suture near its anterior third; the surface is marked by a longitudinal furrow; the exopodite is straight and narrow; both rise side by side, from a common triangular basal joint.

The three slender distal articulations of the maxilliped are not preserved.

The Abdomen.—The abdomen is composed of seven articulations; but the fifth and sixth joints appear to be soldered together in the male. In the female the seven articulations are distinct, and increase slightly in breadth from the first to the fifth, when they again decrease, terminating in a broadly oval extremity.

In the male, the seven articulations gradually but slowly decrease in breadth to the seventh, which is bluntly rounded at its extremity.

In the female, the first three segments are nearly linear; but they gradually increase in length as well as in breadth, to the sixth joint. In the male the first two segments are also nearly linear; but the third and fourth are nearly equal in length to half their breadth, whilst the conjoined fifth and sixth segments are proportionally longer than wide. The seventh, or terminal segment, in the male, is very small, as compared with the same segment in the female.

The abdomen is without ornamentation; but the caudal segments are slightly trilobate in the female.

* The *Plastrosternum* (which is homologous with the thoracic segments of less highly cephalized forms) is really composed of *seven* plates; but the two most anterior, which bear the two pairs of maxillipeds or jaw-feet are very small and are concealed beneath the matrix.

Chelæ.—The first pair of limbs are nearly equal in size; the inner margin of both the fixed and the movable digit of the chelæ is armed with small irregular-sized teeth; one of the hands is slightly more tumid than the other; the forearm, or wrist, is armed with a somewhat prominent spine on the inner margin, and its distal margin is triangular in outline on the upper surface. The arm is short, straight, and robust (Pl. I. figs. 1 & 2).

Walking-feet (2nd 3rd and 4th pairs).—The three succeeding pairs of limbs are rather slender and compressed, the terminal joint long and tapering (Pl. I. figs. 1 & 2).

Fifth pair.—The fifth pair are wanting; but from the projecting position of their primary or basal joints (well seen in one of the specimens obtained by Mr. Meyer) they may have been modified as in the living species of *Portunidæ*, so as to fulfil the office of swimming-feet.

Antennæ.—The antennæ are not preserved.

I subjoin a list of the principal measurements of *R. bispinosa*, obtained from the new specimens in Mr. Meyer's collection.

Length of carapace, from the rostrum to the posterior border, in the *largest specimen* (Pl. I. fig. 1), $1\frac{1}{2}$ inch; breadth to base of epibranchial spines, $2\frac{1}{4}$ inches; breadth to tips of epibranchial spines, $4\frac{1}{4}$ inches; breadth of the posterior border of the carapace, 1 inch.

Another smaller individual, in which both the epibranchial spines are preserved, also measures nearly $4\frac{1}{4}$ inches from tip to tip of spines.

The figures on the plates are all of the natural size, the restored figures giving the size of the *largest* specimens in Mr. Meyer's collection in which both the spines, the chelæ, and the running-legs are preserved.

LITORICOLA*, gen. nov. Pl. II. figs. 1–5.

Carapace about one third broader than long, greatest breadth of carapace between the epibranchial spines. Length of carapace equal to breadth of anterior border; breadth of posterior border equal to half the greatest breadth of carapace.

Carapace smooth, or nearly so; anterior angles of carapace truncated; marginal dentations small; rostrum squarish, bent downwards; orbits (and eyestalks†) long.

Chelæ smooth, flattened, of unequal size (smallest in the female?) Legs well adapted for running.

Underside and abdomen.—At present unknown.

It affords me no little gratification to be able to add another genus to our small list of Fossil Shore-Crabs.

In December 1867 I published the figure and description of *Goniocypoda Edwardsi*, a new genus of British fossil Shore-Crabs, from the lower Eocene of High Cliff, Hampshire (see Geol. Mag. 1867, vol. iv. p. 529, pl. xxi. fig. 1).

This was the first instance of a fossil Crab occurring, belonging either to the *Ocypodidæ* or to the *Grapsoididæ* (forming Milne-

* From *litus*, shore, and *colo*, I inhabit.

† Only a trace of what appears to me to be an eyestalk remains.

Edwards's tribe *Catométopes*), save the undoubted Eastern forms figured and described by M. Desmarest so long ago as 1822, belonging to the genera *Grapsus*, *Gonoplax* *, *Gelasimus*, and *Gecarcinus*.

The occurrence of these forms in our Eocene deposits tends to confirm (if confirmation were necessary) the conclusions already arrived at by Sir Charles Lyell and other eminent geologists (on the evidence of the land animals, marine shells, fossil fruits, and other organisms found in these deposits)—namely, that they attest the existence of a warmer climate than that which we enjoy in the same latitude at the present day.

There is moreover throughout these Eocene deposits, frequent evidence of the proximity of land, indicating that they were laid down in an estuary or near the shore.

Litoricola glabra, H. Woodw. Pl. II. fig. 1.

Of the four specimens representing this genus I have been able, after careful study, to form two species, the larger of which I propose to name *Litoricola glabra*.

The carapace of this crustacean is remarkably smooth ; and it requires considerable patience and lengthened examination (with oblique light) to make out the regions on its surface. The broadest measurement is at the angles formed by the epibranchial spines, where the carapace is 15 lines broad ; the anterior border measures 11 lines, and the posterior 6 lines ; the length of the carapace is 11 lines. The hepatic margin is entire, being only marked by a single spine at each lateral angle, and one at each anterior angle, which is separated only by a notch from the outer orbital spine ; the orbital border is straight, and measures 2 lines in length ; the frontal or rostral border measures 3 lines in breadth ; is plain and bent down, so as to form almost an obtuse angle with the rest of the carapace ; the eyes appear to have been provided with rather long eye-stalks as in *Macropthalmus* and other genera of land-dwelling shore-crabs.

A somewhat sinuous line marks out the epicardiac and metacardiac lobes, the epibranchial, mesobranchial, and metabranchial being also indicated by three nearly equidistant divergent lines ; the hepatic region is small : the gastric region forms the most tumid portion of the carapace ; a slight depression passes from it anteriorly, so as to form a shallow groove down the centre of the frontal border or rostrum.

First pair of Limbs.—The arm is small and slender, the forearm or wrist short, slightly angular and armed with three minute spines at its distal edge ; the right hand is about one third larger than the left ; but in imparichelate forms the hands are not constantly larger on one side.

The four succeeding pairs of limbs are long and flattened, and agree closely with the typical running-forms among living crabs. The terminal joints are long, slender, and pointed.

The first specimens from this locality (described by me in 1870)

* The *Gonoplax* of Desmarest is really a *Macrophthalmus*.

were in a hard quartzite matrix (like the sarsen stones) and almost incapable of development, on account of the intense toughness of the matrix.

The present examples are from a fine sandy loamy bed, which allows of the fossils being readily extracted; but they are usually in a most friable state, and constantly give way, owing to their imperfect fossilization and to cavities in their interior not filled up solid by the matrix. The specimen here described (from Mr. Caleb Evans's collection) is in this crumbling state, and I have had great anxiety on account of its unsafe condition.

It is to be hoped that others may be found of this new and interesting type.

Litoricola dentata, H. Woodw. Pl. II. figs. 2–5.

This species is considerably smaller than the preceding one; like it the surface of the carapace is smooth and destitute of those strongly marked divisions which characterize many forms among the Portunidæ and Canceridæ. The relative proportions of the carapace are about the same.

Anterior border 8 lines; posterior border 5 lines; greatest breadth (at the angle formed by the two lateral or epibranchial spines) 12 lines; greatest length 8 lines. Each branchial border is armed with a single small spine just behind the epibranchial spine which marks the greatest breadth of the carapace.

The hepatic margin is marked by three nearly equal spines, the anterior one being confluent with that forming the orbital border.

The orbits measure 2 lines in breadth; the margin appears to be straight; the frontal or rostral border projects and forms the inner boundary to the orbits, it is 3 lines in breadth, and is deeply furrowed down the centre, which is bent downwards (as in the preceding species), and appears to be blunt in front, with a slightly raised border. The regions of the carapace differ but slightly from those of *L. glabra*, save that the cardiac region is more expanded posteriorly, and less broad in front.

The hands are unequal in size, as in the preceding species. The four pairs of running-feet are flattened laterally, and well suited for rapid locomotion on land.

Only two specimens of this crab, displaying the dorsal aspect, are preserved: the other two examples exhibit the ventral aspect; but, save for the limbs, they do not offer any clear evidence of the abdomen or the plastrosternal plates or maxillipeds.

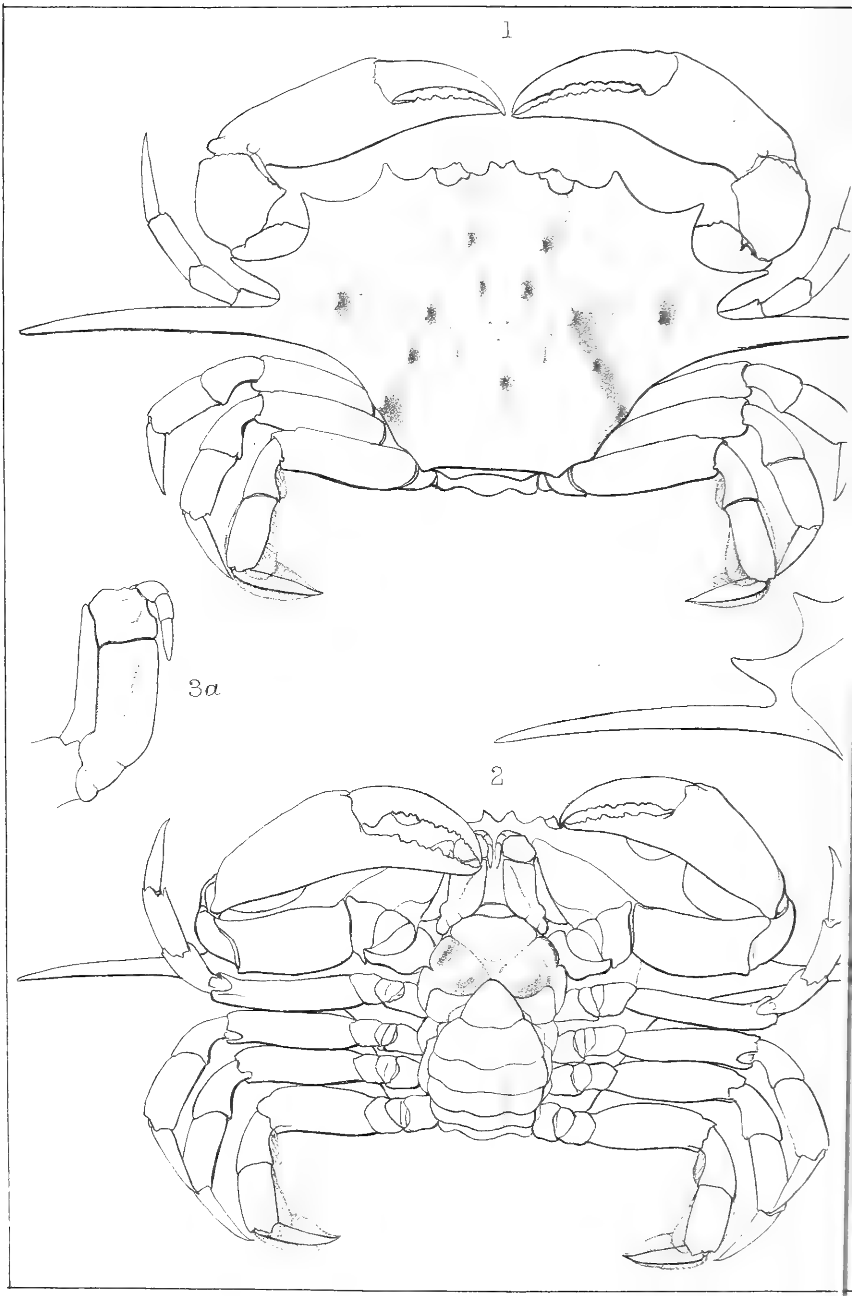
The specimens of *L. dentata* are all from the cabinet of Mr. C. J. A. Meyer, F.G.S.

EXPLANATION OF PLATES.

Plate I.

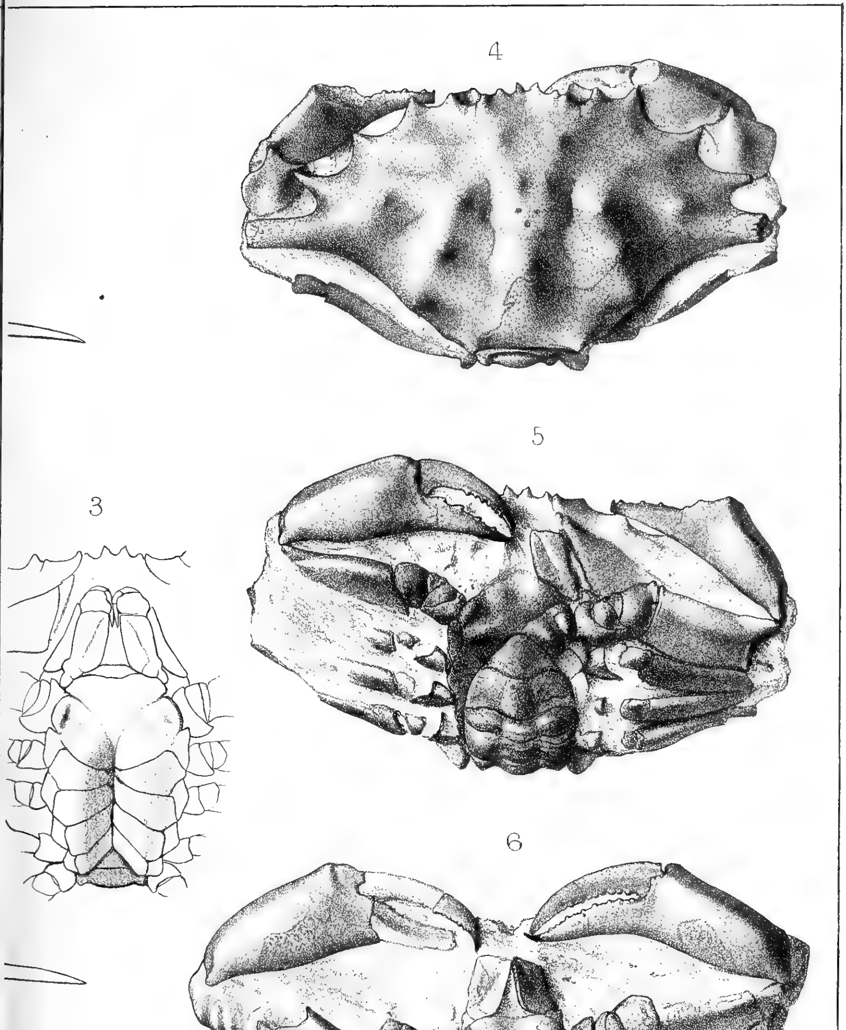
Figs. 1–6. *Rhachiosoma bispinosa*, H. Woodw.

Fig. 1. Outline figure, natural size, of largest specimen in Mr. Meyer's collection, restored from the details furnished by other examples of the same species.



C.L. Griesbach. del et lith.

RHACHIOSO



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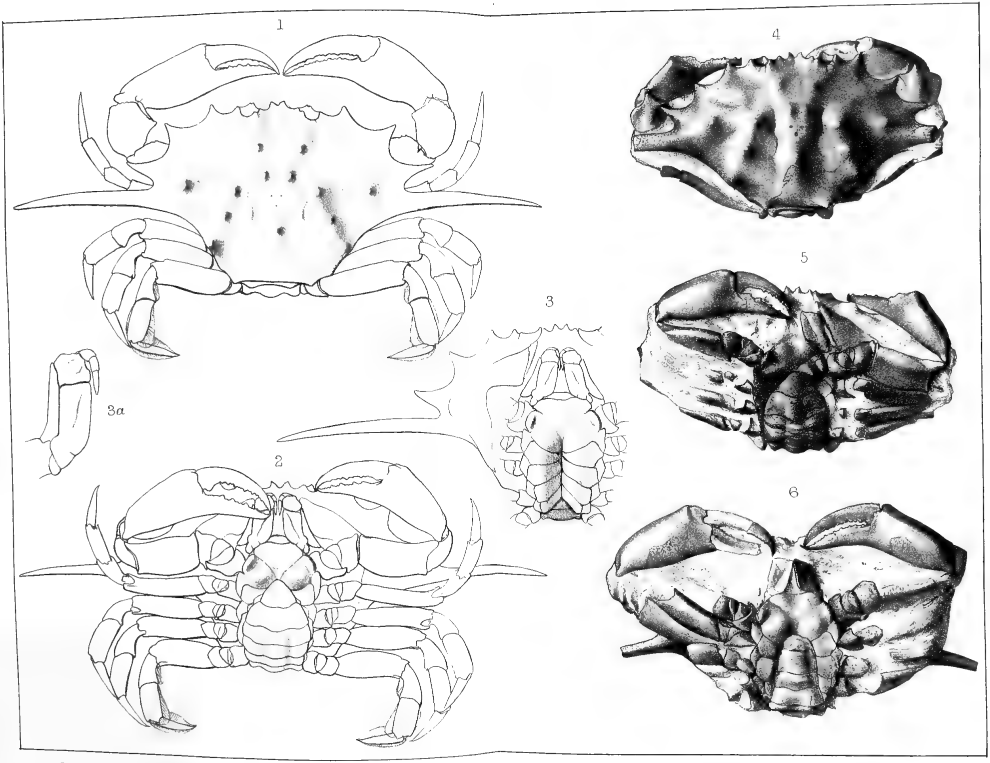
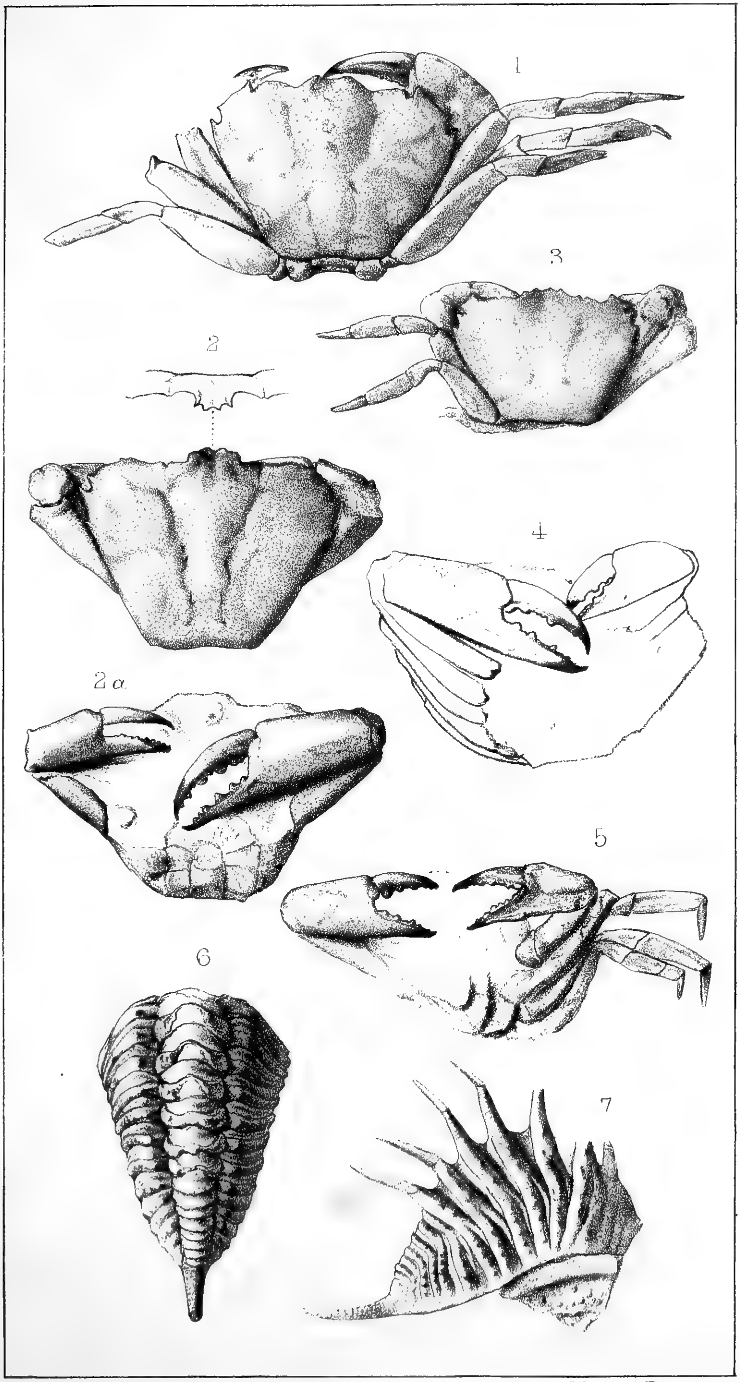
A BISPINOSA.



C.L. Griesbach. del et lith. Mintern Bros. imp.

RHACHIOSOMA BISPINOSA.



C. L. Griesbach del et lith.

Mintern Bros. imp.

LITORICOLA AND ENCRINURUS.

Fig. 2. Outline figure of underside (♀), restored on the same scale as fig. 1.
3. Outline figure of part of underside (♂), on the same scale as fig. 1. Fig. 3*a*. One of the maxillipeds, enlarged.
4. Dorsal aspect of a smaller example (♀).
5. Ventral aspect of the same, showing the broad abdomen and the maxillipeds.
6. Ventral aspect of another specimen (♂), showing the narrow abdomen and the maxillipeds.

All the specimens are drawn of the *natural size.*

Figs. 4, 5, and 6 are not in any way restored.

The above are all from the collection of C. J. A. Meyer, Esq., F.G.S., and obtained from the Lower Eocene of Portsmouth.

Plate II. figs. 1–5.

Fig. 1. *Litoricola glabra*, H. Woodw. Dorsal aspect (the only specimen at present obtained).
2. —— *dentata*, H. Woodw. Dorsal aspect. Fig. 2*a*. The same. Ventral aspect.
3. —— ——. Dorsal aspect of a much smaller individual, in which the legs are preserved.
4. —— ——. Ventral aspect of another specimen, showing the disparity in the size of the chelæ on the opposite side to that in fig. 2*a*.
5. —— ——? Another specimen, perhaps belonging to a *third* species (?), in which the hands are of nearly equal size (? ♀).

All drawn of the natural size; and all from the Lower Eocene of Portsmouth.

Fig. 1 from the Collection of Caleb Evans, Esq., F.G.S.

Figs. 2–5 from the Collection of C. J. A. Meyer, Esq., F.G.S.

Discussion.

Mr. Meyer gave some particulars as to the horizon from which these fossils were derived. They all came from the argillaceous sands with *Dentalium*, mentioned in his former paper. These beds are much mottled, probably owing to the burrowing of the crabs.

Mr. Woodward, in answer to inquiries, pointed out that these crustaceans were of purely littoral, and not of pelagic forms, and their feet were in a condition better adapted for walking than for swimming. The long epibranchial spines formed weapons of offence, and were of much service to the pelagic forms, though their retention in the littoral forms was not of easy explanation. The *Litoricolæ* were essentially adapted for running on land and burrowing. As an instance of the disparity in the hands of Crabs, he instanced the common Calling Crab, which had always one hand greatly larger than the other.

4. *On a* New Trilobite *from the* Cape *of* Good Hope. By Henry Woodward, Esq., F.G.S.

[Plate II. figs. 6–7.]

Since the contributions to the 'Transactions' of this Society, by the late Mr. J. W. Salter, in 1852*, I do not remember that any Trilobites have been described from the Cape of Good Hope.

* Read November 17, 1852, see Trans. Geol. Soc. vol. vii. second series, p. 175.

It is therefore with great pleasure that I lay before this Meeting an entirely new form, which I have referred to the genus *Encrinurus*, from the Cock's-comb Mountains at the Cape, collected and forwarded, together with some new and singularly interesting reptilian remains and other fossils, to the British Museum by Dr. W. Guybon Atherstone, F.G.S, of Graham's Town, Cape of Good Hope.

The specimen is preserved in a nodule of about the size of a 7 lb. cannon-ball, and exhibits on one piece the dorsal aspect of the segments of nearly the entire body, save that the head is folded under, on the other a profile of the fossil in intaglio, which gives a most instructive view of the Trilobite, and shows that originally each of the eleven thoracic segments was probably furnished with a median dorsal spine five lines in length, giving to it a crested appearance suggestive of the specific name of *crista-galli*—a name doubly appropriate, as the specimen was obtained from the *Cock's-comb* Mountains.

The caudal series, or pygidium, although not furnished like the thoracic series with a row of dorsal spines, is terminated by a caudal spine rather more than $\frac{1}{2}$ an inch in length. These spines are rendered still more novel from the fact that they are *annulated* from their bases to their tips, thus giving them much the same aspect as the little Silurian Annelide tubes known as *Tentaculites annulatus*.

The axis of each thoracic ring is moreover ornamented by the addition of from two to three tubercles on either side of the great central spine, and with from four to five tubercles on the ridge of each of the pleuræ.

The axial ridges are very prominent, as is also the raised posterior portion of each of the pleuræ; the anterior fulcral portion of each rib is also clearly seen divided by a deep furrow, as are each of the thoracic segments from the preceding and succeeding somite. The margins of the pleuræ are slightly expanded; and their lateral borders appear to have been obtuse.

Each of the eight segments composing the pygidium has its axial and pleural ridges ornamented in like manner with tubercles; the furrows between the axial ridges are also proportionally deep. We cannot describe the head, save to observe that the surface was covered with rounded tubercles—a character seen in other *Encrinuri*.

The occurrence of spines is by no means a rare feature in the ornamentation of Trilobites; the genera *Homalonotus*, *Arges*, *Acidaspis*, *Lichas*, *Bronteus*, are familiar examples; but *Sao hirsutus*, of Barrande, a Lower Silurian (Bohemian) form, alone has such a line of axial spines as is seen in this form from Africa.

But the spines in *Sao* are very minute, and extend moreover continuously along the axis of the pygidium also, which is not the case with the African species. The number of the segments, as well as their form and that of the pygidium, point to *Encrinurus* (and not to *Sao*) as the genus for the reception of this crested species. Nor is it altogether anomalous; for in our British *Encrinurus punctatus* specimens occur with one, two, and *even three* axial spines on the

posterior thoracic segments, and others may yet be discovered with even a larger number.

In development, such organs must necessarily be removed; not one *fossil-cleaner* in a hundred would again put upon a trilobite eleven spines which he had removed; and in *many instances* such appendages may have been overlooked.

The occurrence of this truly remarkable specimen may cause fresh interest to be awakened among the numerous collectors of these attractive fossils, and so lead to an increase of knowledge concerning the group.

Dimensions of *Encrinurus crista-galli*: total length (including head) $3\frac{1}{4}$ inches; breadth of thorax $1\frac{1}{4}$ inches.

EXPLANATION OF PLATE II. figs. 6 & 7.

Encrinurus crista-galli, H. Woodw.

Fig. 6. Dorsal aspect of specimen.
7. Profile (drawn from a cast of the intaglio side of the nodule enclosing the specimen) showing the dorsal and caudal spines, and the head bent under the anterior segments, but only very imperfectly preserved.

Both figures of the natural size.

Obtained by Dr. W. Guybon Atherstone, F.G.S., of Graham's Town, in breaking open a nodule of dark claystone of Silurian (or Devonian?) age; Cock's-Comb Mountains, Cape of Good Hope.

The specimen has been presented by Dr. Atherstone to the British Museum.

Discussion.

Mr. Evans called attention to the importance of examining the matrix out of which fossil trilobites were extracted, as, were it not for the matrix, the spines on this specimen would have escaped observation.

Mr. Woodward stated that he had not until the day of the Meeting been able to examine the trilobites collected at the Cape by the late Mr. Bain, and had at first sight doubted whether the fossil he had described might not be identical with *Typhloniscus Bainii* of Salter; but on closer examination he was inclined to consider it distinct. He preferred for the present retaining the name of *Encrinurus* for the genus, but still with some doubt.

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5. *On an* Extensive Landslip *at* Glenorchy, Tasmania.

By S. H. Wintle, Esq.

(Communicated by Prof. Ramsay, F.R.S., V.P.G.S.)

On the 4th of June last this colony was visited by a very heavy rainfall, which continued without intermission for twenty-four hours, when $4\frac{1}{2}$ inches of rain fell, causing most disastrous floods in many parts of the island. While the citizens of Hobart Town were actively employed in trying to save life and property from the raging torrent that rushed through the heart of the city, news arrived of a most extensive landslip having occurred during the night at Glenorchy,

five miles distant from Hobart Town, which had entirely altered the physical features of a considerable portion of that district, besides causing loss of life and wide-spread desolation.

Upon the cessation of the storm, I at once started for the scene of the catastrophe; and, upon arriving at O'Brien's Bridge, I found that rumour had not in this instance travelled on the wings of exaggeration. From this point, distant five miles from Mount Wellington, it could be seen that a large portion of the northern face of that mountain had given way, and, descending to a depth of nearly 2000 feet into the bed of the rivulet which takes its rise at that point, had carried destruction and desolation on either hand. This mountain-torrent, after pursuing a very tortuous course, and having a mean descent of 9° for about six miles from its source, empties itself into the river Derwent, about one mile from the township of Glenorchy.

The scene which presented itself at this locality was one that could never be forgotten. Huge trees, some of them more than 200 feet in height when standing, were piled up in vast heaps, presenting an entangled mass of timber, boulders, casks, fences, agricultural implements, and various other objects. Such had been the force of the torrent that not a vestige of bark, branches, or roots could be seen for the most part on these transported trees, while even the blue gum (*Eucalyptus globulus*), which is among the hardest and toughest of Tasmanian woods, not only had its massive protuberances ground down smooth with the trunk, but reduced to fibre where the trunk had been snapped short off.

Finding it completely impracticable to approach the landslip on this occasion, owing to the condition of the country, I was compelled to return; but I renewed the attempt a few days afterwards. Starting from O'Brien's Bridge, I took up the bed of the rivulet. This I found to be occupied by carboniferous limestone, a formation which is well developed in this part of the island. This limestone, which, as a rule, teems with Brachiopodous remains (the most abundant of which are *Spirifera producta* and *Terebratulæ*) and an equal abundance of Bryozoa, has been exposed by the erosion of the torrent for more than two miles. In those places where the *débris* deposited by the flood have left natural sections of this formation fully exposed, I find the blue, crystalline, shelly limestone alternating with beds of mudstone and thin interstratifying shales. I mention this fact for the reason that hitherto Tasmanian geologists have regarded the mudstone deposits as upper members of the Carboniferous limestone series. This mudstone, I may observe, contains, as far as known, the same species and genera of fossil Testacea and corals as the true limestone; but it differs from the latter in the important particular of yielding only the *casts* of those organisms—being, in short, entirely devoid of carbonate of lime.

At the distance of one mile, or thereabouts, from O'Brien's Bridge, I found still more striking evidence of the power of the torrent than that already referred to. This consisted in both banks of the rivulet being lined for a considerable distance with small angular fragments

of close-grained dioritic greenstone, sharp at their edges as gun-flints, and all presenting fresh fractures. These fragments were the result of large masses of that rock (which composes the mountain-summit) having been hurled with terrific violence against each other by the fury of the torrent. It would be no exaggeration to say that some of the blocks of greenstone which have been transported from the mountain-side to a distance of three or four miles weigh many tons.

Having proceeded about two miles along the course of the rivulet, over limestone, greenstone then makes its appearance, rising into lofty hills on both sides of the watercourse, and covering up the limestone and its associated strata for fully one mile and a half. To the eruption and overflow of this igneous rock is to be ascribed the before-mentioned tortuous character of the rivulet's course, to which, as I shall eventually endeavour to show, must be traced the ruin and desolation that followed.

Close to the base of the great landslip, the limestone is again exposed in the bed of the rivulet, where superincumbent deposits have been recently removed by the flood. The beds have a dip of 10°, W.S.W., towards the mountain, and a strike nearly due north. A very excellent section of them is here exposed in stair-like ledges, the upper surface displaying much metamorphism by contact with the greenstone. The following Table gives their descending order and respective thickness:—

	Thickness, feet.
1. Brown, thick-bedded sandstone. Upper surface altered for more than 1 foot in depth into a semivitreous mass, and presenting more or less rhomboidal joints	20
2. Arenaceous conglomerate, containing worn fragments of decomposed granite, clay-slate, quartz rock, and mica-schist. Upper surface also metamorphosed	10
3. Dark blue mudstone, studded with angular fragments of quartz, altered, and presenting joints	8
4. Coarse sandstone, containing rounded fragments of a quartzose rock, altered near surface into a compact crystalline mass with rhomboidal joints	11
5. Blue carboniferous fossiliferous limestone, replete with *Spiriferæ*, *Producti*, Terebratulidæ, and *Fenestella*, altered near surface; rhomboidal joints	12
6. Blue mudstone conglomerate, with casts of the foregoing shells and corals. Altered near surface	100
7. Greenstone, fine, close-grained, and compact, lying conformable to the above strata.	

The inference to be drawn from the foregoing facts is, that the different strata here treated of presented, at the time when the greenstone composing Mount Wellington was ejected, the same broken and stair-like surface that they do now, and the overflow filling up the inequalities of the older sedimentary rocks produced their metamorphosed character at the point of contact.

At the distance of about two thirds of a mile from this natural section the foot of the great slip is gained, the intervening space being occupied by polished greenstone having an angle of 10°, the

smoothness being due to the grinding process carried on by the transport of immense masses of rock from the head of the mountain during periodical floods.

The sight that bursts upon the beholder from this point is terribly wild indeed. Stretching above him to a height of more than 1000 feet is an enormous tract having a mean inclination of 32°, and strewed with prostrate battered trees of gigantic dimensions, and ponderous blocks of greenstone, many tons in weight, half-buried in yellow clay and sludge. A clean sweep has been made in the centre of the denuded tract, baring the underlying greenstone and forming a new channel many feet in depth.

It was with very great difficulty that I reached the top of the slip by skirting its margin, which is densely timbered with huge gum-trees and thick underwood. The face of this steep is thickly covered with great masses of fallen greenstone, while its mean angle, as furnished by the clinometer, is 42°. This fallen rock is evidently the result of a former landslip, since clothed by the timber it now bears. The character of this escarpment, as indeed the whole of the ground surrounding the landslip, furnishes an excellent idea of the quantity of rock, timber, and soil which was precipitated into the gully beneath. Upon examining the head where the mass broke away, I found the greenstone to be highly laminated, and presenting a slope of 43°. Above this, there is a bank of drift from the higher ground 20 feet in depth and consisting of smaller fragments of greenstone and gravel imbedded in a matrix of yellow clay.

As this cataclysm occurred between 10 and 11 o'clock at night, no eye beheld what part of the mountain-side first gave way; but, taking into consideration the incoherent nature of the soil and surface of the bottom rock at this part, and also the very great incline, I am disposed to think that the dislocation happened at this point, through supersaturation and undermining by the great water-flow from the head of the mountain.

Upon extending my examination to the surrounding localities, I found that not an acre exists, having a mean inclination of 30°, but what bore the most convincing evidences of having been the scene of landslips in by-gone times. As a rule in this island, wherever trap-rocks obtain in the mountain having an inclination of between 25° and 30°, fallen masses of such rocks are usually met with at an average height of from 2000 to 3000 feet above the sea-level, thus affording, as I take it, countless examples of these landslips. Nor can this be regarded as a matter for marvel when the precipitous character of the mountain-system of Tasmania, wherever the trappean series of rocks abound, is taken into consideration.

The altitude of the head of this landslip I estimate to be about 3000 feet above the sea-level. I was, however, unable to determine it with precision, owing to my mountain-barometer having met with an accident. In arriving at this conclusion I am guided by a knowledge of the altitude of adjacent heights.

In looking at the watershed which collected the aqueous force

necessary to remove so large an area of the surface of a mountain's side, and then remembering the terrible effects produced in the lower regions, the mind of the geologist is constrained to have recourse to an accumulation of such power and its sudden liberation. In traversing the bed of the rivulet it is seen that where the carboniferous limestone obtains in the lower levels, there the huge trees and rock-masses brought down by the torrent began to be deposited. But when the greenstone formation is reached, which, as before mentioned, rises in lofty hills on either side of the channel, giving to it its labyrinthine course, startling evidence of the force of the obstructed deluge is to be seen. The escarpments of these hills bounding the rivulet are so arranged that, could both sides of the gully be made to meet, they would fit into each other like the serrated edges of a cranial suture. The first thing which strikes the observer at this point is, that the water had swept every thing before it to a height of 60 feet on one side of the gully, and only reached to 12 or 15 feet on the opposite side. This feature is to be seen alternating until the foot of the landslip is reached. This phenomenon is to be accounted for, I believe, in this way.

When the first mass of earth gave way, at or near the head of the slip, it formed an embankment or dam where the angle of the incline is least; the accumulated water at last bursting its bounds, the whole mass was precipitated into the gully below, carrying all before it, and, striking the point of the hill at the bottom, a great wave of deflection would be hurled on the opposite side, where an indentation exists; and much of its force being now expended, another dam was formed by the huge trees and rocks; and thus a repetition of disruptions of bodies of water occurred. This is to be seen in several parts of the rivulet by the arrangement of the stones. When the first great body of water had been thrown to a height of 60 vertical feet on one side of the gully, it deposited at its edge the trunks of enormous trees. One of these I found upon measurement to be 103 feet long, without the sign of a branch, and 6 feet in diameter at its base. It had been snapped off short at the smaller end, which gave a diameter of 4 feet 2 inches. These trees were lying parallel to the direction of the wave. Close to this spot, on the same escarpment, stood trees of equal size without a vestige of bark, that had been broken off 30 feet from their base. A few hundred yards from this spot one large blue gum-tree had fallen right across the gully and snapped in three places. This tree measures in length 213 feet, with a diameter in the middle of 4 feet 9 inches. In some instances masses of greenstone had been driven into the solid wood as though propelled from a cannon.

That this landslip has been the greatest geological mutation in this island within the memory of man there cannot be a doubt; but it is only one of many thousands that have taken place on a similar scale during the Tertiary epoch.

For more than a square mile in the flat low-lying area occupied by the township of Glenorchy, water-worn masses of greenstone, limestone, and sandstone are seen to a depth of

3 feet on the average, wherever the diluvium of loam and clay has been removed by fluviatile agency. This deposit has been made by numerous floods of this nature. At such a time the channel is considerably altered—cutting away its bank on one side, and depositing material on the other. In this way the rivulet may be said to have travelled backwards and forwards through ages, ever rearranging the old rounded material. The period, however, required for these changes may be faintly conceived by the fact that in many parts there are 20 feet of Tertiary drift reposing on this bed of rounded stones. This fact has led some intelligent colonists to regard these rounded stones as indicating the bed of an ancient river. Wherever a rivulet, taking its rise from the mountain-regions in this island, disembogues its waters, a similar deposit of rounded stones is to be seen. At Sandy Bay, for instance, only two miles from this city, at the mouth of a rivulet, such a deposit is seen covered with comminuted shells of recent species to a depth of from 8 to 10 inches; and these again are overlain by two or three feet of vegetable soil*.

At the springs on the south-western side of Mount Wellington there are evidences of just such another landslip having taken place in former times. Here the side of the mountain has about the same angle as that at Glenorchy; but the altitude is somewhat greater at this spot, which is now densely timbered. Huge portions of greenstone columns, which have descended from the head of the mountain, are seen reposing in actual contact with the *Endogenophyllites*-shale (*Endogenophyllites* being the name given by Professor M'Coy to a new plant-impression which I discovered in that formation). The "Ploughed Fields," as they are locally called, of this mountain, to which I referred in my "Sketch of the Principal Features of the Geology of Hobart Town," read before the Society a few years ago †, are also to be traced to the same cause.

Before I started upon my examination of the site of the slip, I made particular inquiry among the residents of the district respecting the sounds they heard when the event took place. One and all informed me that at first they thought an earthquake had happened —that at five miles distance a rumbling roar was heard at intervals, and it was not till some time had elapsed from the first sound that the destructive body of water made its appearance at the township. This statement fully coincides with the evidences of a series of embankments having been formed, as before mentioned.

Owing to the subject of this paper being one of no small importance at the stage of geological inquiry in this part of the globe, as showing the powerful effects of rainfall as a modifying geological agent, I have been induced to extend my remarks beyond what may be regarded as ordinary limits. Much I have left unsaid relating to more minute details, but hope to supply them at a future date.

Discussion.

Mr. W. T. Blanford mentioned somewhat similar landslips as

* *Vide* paper read by me before the Royal Society of Tasmania, on the 12th April, 1864.

† Quart. Journ. Geol. Soc. vol. xx. p. 465.

occurring in the eastern Himalayas, and on fully as extensive a scale. In some cases not only the loose soil, but large masses of solid rock were carried down.

Mr. DREW mentioned other instances in India of a similar character, but thought that in the western Himalayas frost also assisted in the work of destruction.

DECEMBER 4, 1872.

Edward Crane, Esq., of St. John's Lodge, Wellington Villas, Brighton; William Abbott Green, Esq., Inspector-General of Hospitals, Bengal, Marchmont House, Leyland Road, Lee, Kent; D. C. Davies, Esq., Conygree House, Oswestry; William Johnston, M.D., 6 Gloucester Terrace, Weymouth; W. M. Cameron, Esq., Drayton Lodge, South Kensington; W. H. Peacock, Esq., Hoyland and Elsecar Colliery, Barnsley; Lieut.-Gen. the Hon. A. H. Gordon, C.B., 41 Warrior Square, St. Leonards; E. Wilson, Esq., Nottingham; and Fitzhugh Bathurst Henderson, Esq., C.E., Plas Gwyn, Gob-Owen, Shropshire, were elected Fellows of the Society.

The following communications were read:—

1. *On the* TREMADOC ROCKS *in the* NEIGHBOURHOOD *of* ST. DAVID'S, SOUTH WALES, *and their* FOSSIL CONTENTS. By HENRY HICKS, Esq., F.G.S.

[PLATES III.–V.]

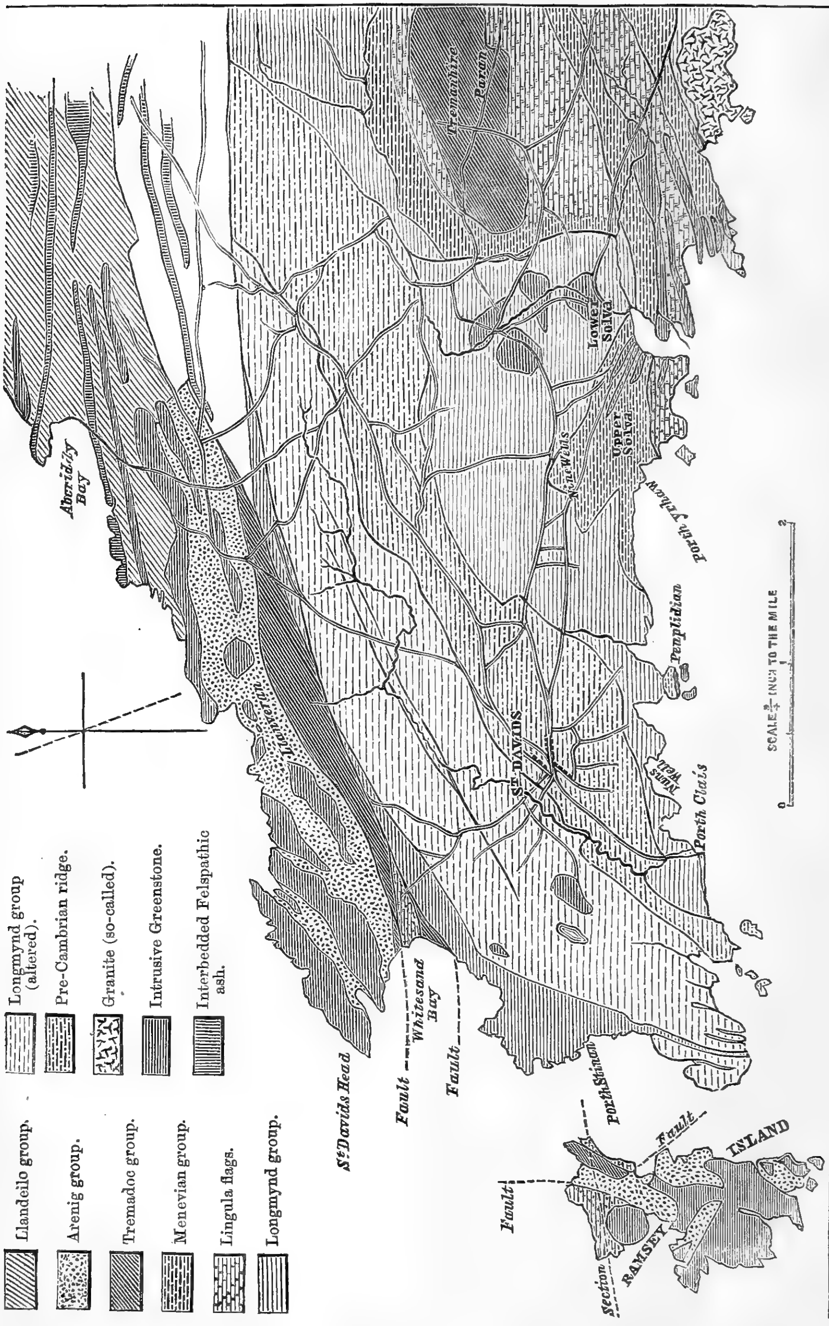
THE occurrence near St. David's, in South Wales, of rocks supposed to be of the age of the Tremadoc Slates of North Wales, was mentioned in a Report by the late Mr. Salter and myself to the British Association in 1866; and a list of the fossils which had up to that time been discovered in them was also given. Several new forms, however, have since been found in these rocks, and some of them very recently, during researches made at Ramsey Island by Messrs. Homfray, Lightbody, Hopkinson, and Kirshaw, in conjunction with myself. The Brachiopoda were figured by Mr. Davidson in his paper "On the Earliest British Brachiopoda," in the Geological Magazine for July 1868; and a supposed land-plant was named by me *Eophyton explanatum* in the same publication for Dec. 1869; but with the exception of these, the whole of the fossils, comprising a rich and exceedingly interesting fauna, are as yet undescribed.

In the present paper I propose to describe all these new forms, and also to give some account of the lithological characters of the strata in which they occur, their relation to the other formations, and their geographical distribution in the neighbourhood of St. David's.

On the map (fig. 1) it will be seen that there are three distinct patches of these rocks shown, viz.:—at Ramsey Island, on the eastern coast; at the north end of Whitesand Bay, and extending for some distance in a N.E. direction; and in a district about five miles east of St. David's, where they occupy a considerable tract of the country.

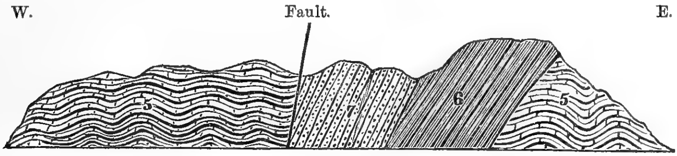
At Ramsey Island they rest conformably on Lingula-flags, which appear here in the usual character of hard siliceous sandstones inter-

Fig. 1.—*Geological Map of St. David's.*



stratified with grey flaky slate containing *Lingulella Davisii* in great abundance. They graduate by almost insensible degrees from these as hard grey flags, then bluish grey, with some thick-bedded rock of tough texture. They have a thickness of nearly 1000 feet, with an average dip of about 60°, and the strike of the beds is from N.E. to S.W. They form the north-east point of the island, and are exposed in an excellent coast-section, with the Lingula-flags dipping under them, and the dark iron-stained Arenig slates resting upon them. It is doubtful, however, whether the latter rest conformably upon them. I am inclined to think that a fault intervenes, and that the proper thickness, as shown at some of the other places, does not occur here in consequence.

Fig. 2.—*Section across the northern part of Ramsey Island* (see Map).



5. Lingula-flags. 6. Tremadoc rocks. 7. Arenig rocks.

At Whitesand Bay they also rest conformably on Lingula-flags; but a fault running up in a north-east direction, and almost in the strike of the beds, has removed more than three fourths of their thickness, and has brought down the Arenig group in contact with them, so as to give it an appearance of resting almost conformably upon them. Further north, near Llanveran, the fault has gone eastward of the series, and they are seen again in nearly their entire thickness underlying the Arenig group.

The third patch, at Tremanhire, in the middle of the country, east of St. David's, occupies a greater area; but there are only a few quarries open, and therefore considerable difficulty has been experienced in defining its proper limits. The Lingula-flags seem everywhere to underlie the series here as at the other places; but the Arenig rocks only come in unconformably at the N. E. end of the patch. The beds have very much the same character as at Ramsey Island, with the exception that the middle portion is more of a sandstone in parts, and less cleaved. Some of the most perfect specimens have been found in these last-mentioned beds near and at a place called Paran on the map.

On the whole, however, Ramsey Island offers the best advantages for examining these rocks, and also for obtaining fossils, as the beds are there well exposed, and literally, in some parts, almost entirely made up of organic remains.

The species which have been discovered in these rocks, with the exception of *Lingulella Davisii*, are all new, as well as a few of the genera. They comprise a new genus of Trilobites, which I have named *Neseuretus*, and of which there are several species. This genus forms an interesting stage between the earlier *Conocoryphe*

on the one hand, and *Dikelocephalus*, *Homalonotus*, and *Calymene* on the other. In its coniform glabella, with bent furrows and faceted pleuræ, it resembles *Conocoryphe*; and in the position of its posterior facial sutures, and in its broad and many-ribbed tail, it resembles *Dikelocephalus*. The only other Trilobites are two species of *Niobe*, a well-known Tremadoc genus. In these two genera we certainly recognize a resemblance to far earlier types, and the possible progenitors of many succeeding forms. The fauna is exceedingly rich in the Lamellibranchiata, no less than twelve species, belonging to five genera, having been found. This is the more interesting as no Lamellibranchs had previously been discovered in so early a formation in Britain—nor, indeed, so far as I am able to find out, in any other country. The Echinoderms also are represented here by a beautiful starfish of the genus *Palasterina*, and by an Encrinite of the genus *Dendrocrinus*, and hence are shown to have existed at a very early period. The Cephalopoda, which have not been found in earlier formations, are also represented here by a species of *Orthoceras*. The remainder of the fauna is made up of Heteropods, Pteropods, and Brachiopods, groups which had representatives in still earlier rocks (see Table).

The conditions under which the Tremadoc rocks in the neighbourhood of St. David's were deposited seem to have been intermediate between those of the shoal and shallow water of the Lingula-flag period and those of the deep sea which must have prevailed when the fine muddy deposits of the overlying Arenig slates were being thrown down. This intermediate condition must have been particularly favourable to the existence of life, and was doubtless one of the causes of the appearance at this time of such a varied and important group of organisms.

In comparing these rocks with the Tremadoc slates of North Wales on stratigraphical grounds, a difficulty arises in the supposed unconformity mentioned by Prof. Ramsay in his memoir on North Wales as occurring there between them and the Lingula-flags—as these two groups, wherever they are exposed in the neighbourhood of St. David's, appear so closely connected, both on stratigraphical and lithological grounds that it becomes quite impossible to know exactly where the boundary-line between them, which of course in such a case is only arbitrary, should be placed. But the palæontological evidence goes to prove that they (the Tremadoc rocks) are closely allied to, if not identical with the lower portion of the Tremadoc rocks of North Wales*.

Mr. Homfray, of Portmadoc, who has carefully studied the

* The faunas, however, are in some respects considerably unlike; but the difference is doubtless to be attributed to the state of the sea at the time the rocks were deposited in each locality. In North Wales the series is made up of fine-grained slates, and hence of deep-sea deposits, and with a deep-water fauna; in South Wales, of rough-grained flags and sandstones, indicating much shallower water, and, as shown by the presence of worm-tracks, numerous lamellibranchs and brachiopods of large size, a comparatively shallow-water or mixed fauna. The absence at St. David's, in the Upper Lingula-flags, of the fine black slates which are so characteristic of the series in North Wales and at Malvern, may also be accounted for by the prevalence of shallow water in the one locality.

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F GREAT BRITAIN.

		fe. / , Orders, &c.	Typical Localities.
MIDDLE CAMBRIAN (*Sedgwick*). PRIMORDIAL SILURIAN (*Murchison*). UPPER CAMBRIAN (*Lyell, Salter, &c.*).	Upper		
	Middle	.	Portmadoc and Dolgelly, in North Wales.
	Lower	, Asteroidea, ppoda. ·anchiata.	Tremanhire, Ramsey Island, and Llanveran, near St. David's, in South Wales.
	Upper (Dol *Belt*)	nts (?).	Malvern, Dolgelly, and near Portmadoc.
	Middle (Ffes *Belt*)	da.	Maentwrog, Dolgelly, and at Ramsey Island, near St. David's.
	Lower Maen *Belt*)	da.	Neighbourhood of Maentwrog, Dolgelly, and St. David's.
LOWER CAMBRIAN (*Sedgwick*). CAMBRIAN (*Murchison*). LOWER CAMBRIAN (*Hicks*).	Menevi	. traca.	St. David's, in South Wales; and neighbourhood of Maentwrog, and Dolgelly, in North Wales.
		a.	St. David's, in South Wales; Harlech, Bangor, &c., in North Wales; Longmynd, in Shropshire; and Bray Head, in Ireland.
	Longm lech	. . raca (?).). Brachiopoda. ?). Annelida.	St. David's.

TABLE OF THE STRATA, AND THE ORDER OF APPEARANCE OF LIFE, IN THE CAMBRIAN ROCKS OF GREAT BRITAIN.

		Lithological Characters.	Thickness of Strata.	Order of the appearance of Life.		Typical Localities.
				Genera.	Classes, Orders, &c.	
MIDDLE CAMBRIAN (*Sedgwick*). PRIMORDIAL SILURIAN (*Murchison*). UPPER CAMBRIAN (*Lyell, Salter, &c.*).	Upper Tremadoc	Iron-stained slates and flags ...	feet. 1000	Angelinia, Conularia, Lingulocaris.		Portmadoc and Dolgelly, in North Wales.
	Middle Tremadoc	Dark earthy slates		Cheirurus, Asaphus, Dictyonema.	Hydrozoa.	
	Lower Tremadoc	Grey flaggy sandstones	1000	Dendrocrinus, Palasterina, Orthoceras, Glyptarca, Davidia, Modiolopsis, Niobe, Ctenodonta, Palæarca.	Crinoidea, Asteroidea, Cephalopoda. Lamellibranchiata.	Tremanhire, Ramsey Island, and Llanveran, near St. David's, in South Wales.
	Upper Lingula-flags (Dolgelly Group, *Belt*).	Soft black and bluish slates in North Wales; bluish and grey flags in South Wales.	600	Eophyton, Neseuretus, Sphærophthalmus, Dikelocephalus ?, Parobolina, Peltura.	Land Plants (?).	Malvern, Dolgelly, and near Portmadoc.
	Middle Lingula-flags (Ffestiniog Group, *Belt*).	Grey arenaceous and micaceous slates and flags.	2000	Bellerophon, Hymenocaris, Buthotrephes.	Heteropoda.	Maentwrog, Dolgelly, and at Ramsey Island, near St. David's.
	Lower Lingula-flags Maentwrog Group, *Belt*).	Bluish slates and flags, and alternating bands of yellowish grey shales and sandstones.	2500	Olenus and a phyllopod crustacean.	Phyllopoda.	Neighbourhood of Maentwrog, Dolgelly, and St. David's.
LOWER CAMBRIAN (*Sedgwick*). CAMBRIAN (*Murchison*). LOWER CAMBRIAN (*Hicks*).	Menevian Group ...	Thick beds of sandstone with shale. Dark blue slates and flags, dark grey flags, and grey gritty beds.	600	Stenotheca, Orthis, Protocystites, Cyrtotheca. Carausia, Entomis, Erinnys, Holocephalina, Anopolenus, Arionellus.	Cystodea. Entomostraca.	St. David's, in South Wales; and neighbourhood of Maentwrog, and Dolgelly, in North Wales.
	Longmynd, or Harlech Group.	Grey, purple, and red flaggy sandstones; yellowish-grey sandstones, shales, and flags; purple sandstones, sometimes with greenish bands; red, flaggy, or shaly beds; greenish flaggy sandstones, conglomerates, and greenish ironstones.	4000 in true succession in South Wales. Supposed to be over 8000 in N. Wales.	Theca. Paradoxides. Obolella. Plutonia. Conocoryphe. Microdiscus. Palæopyge. Haughtonia. Agnostus*. Histioderma. Protospongia*. Scolithus. Leperditia (?). Arenicolites. Discina. Oldhamia. Lingulella.	Pteropoda. Trilobita. Spongida. Entomostraca (?). Plantæ (?). Brachiopoda. Polyzoa (?). Annelida.	St. David's, in South Wales; Harlech, Bangor, &c., in North Wales; Longmynd, in Shropshire; and Bray Head, in Ireland. St. David's.

* Found recently at the base of the Cambrian Rocks of St. David's.

Tremadoc rocks of North Wales for some years, states that he has no difficulty in recognizing in these beds at St. David's the equivalents of the lower portion of the series in his district; and as evidence of their parallelism he mentions the occurrence of *Niobe*, *Dikelocephalus* (*Neseuretus*?), and an *Orthis* similar to one of the species at St. David's, but smaller, at the base of that series. It is also an interesting fact that the genus *Niobe* in both districts is only found in these lower beds; and, again, the *Dikelocephalus* mentioned is truly a *Neseuretus*, a genus which, I think, will be proved to belong to this horizon, not only in this country, but also in Canada and the United States. Prof. Hall, in 1863, in his 'Preliminary Notice of the Fauna of the Potsdam Sandstone of the Upper Mississippi Valley,' mentions that the typical species of the genus *Dikelocephalus* do not appear until we get to the later stages of the formation. This is well borne out also by researches in this country; for the forms doubtfully figured and described by Mr. Salter (in the Appendix to Prof. Ramsay's memoir) as *Dikelocephalus* from the Upper Lingula-flags and from the Lower Tremadoc rocks, are, in my opinion, species of *Neseuretus*, and the only true *Dikelocephalus* found in Wales is the *Dikelocephalus furca* from the Upper Tremadoc rocks of North Wales.

The Upper Tremadoc rocks are, in Mr. Homfray's opinion, represented at St. David's by the so-called Arenig rocks, which are known to contain several Upper Tremadoc fossils in addition to the rich fauna of Graptolites discovered during our recent researches, and which have been recognized by Mr. Hopkinson as belonging to the age of the Quebec group of Canada. According to Mr. Homfray some of these graptolites also have been discovered by Mr. Ash in the Upper Tremadoc rocks of North Wales.

In the present paper, however, I have only included the rocks below the so-called Arenig group, as known at St. David's, in the Tremadoc group, believing that the two formations are sufficiently distinct lithologically and palæontologically to be separately considered.

If Mr. Homfray's supposition, however, is proved to be correct (and it is supported by the fact that the Tremadoc series as hitherto considered is much greater in thickness in North Wales than in South Wales, and the Arenig series much less), I think it will necessitate the doing away with the name Upper Tremadoc, and also a change in the boundary line, hitherto placed above the Upper Tremadoc, and which has been looked upon as of considerable importance in stratigraphical classification, to its base, as the whole Arenig series is much more intimately allied to the overlying Llandeilo slates than it is to the underlying Tremadoc rocks as exhibited at St. David's.

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and of a deep sea in the other, at the same time. It is not at all unlikely also that the lower portion of the Tremadoc series at St. David's was deposited contemporaneously with the black beds of the Lingula-flags of North Wales, as in both cases they are the first indications of a change taking place in the sea-bottom after the long period of the shallow sea in which so many thousand feet of Lingula-flags and sandstones were deposited.

The following is a list of the fossils discovered in the Tremadoc rocks of St. David's:—

Neseuretus ramseyensis, sp. n.
—— quadratus, sp. n.
—— recurvatus, sp. n.
—— elongatus, sp. n.
—— ——, var. obesus.
Niobe menapiensis, sp. n.
—— solvensis, sp. n.
Theca Davidii, sp. n.
Orthoceras, sp.
Bellerophon ramseyensis, sp. n.
—— solvensis, sp. n.
Palasterina ramseyensis, sp. n.
Dendrocrinus cambriensis, sp. n.
Ctenodonta menapiensis, sp. n.
—— cambriensis, sp. n.
Palæarca Hopkinsoni, sp. n.
Palæarca oboloidea, sp. n.
Glyptarca primæva, sp. n.
—— Lobleyi, sp. n.
Davidia ornata, sp. n.
—— plana, sp. n.
Modiolopsis ramseyensis, sp. n.
—— Homfrayi, sp. n.
—— solvensis, sp. n.
—— cambriensis, sp. n.
Lingulella Davisii, *M'Coy*.
Lingula petalon, *Hicks*.
Obolella plicata, *Hicks*.
Orthis Carausii, *Salter*.
Orthis menapiæ, *Hicks*.
Eophyton explanatum, *Hicks*.

Description of the Fossils.

Neseuretus, gen. nov.

Head semicircular. Glabella tapering forwards, moderately convex, and marked by three pairs of furrows, which reach about a third of the distance across, but usually bend backwards at their extremities. Eyes prominent, and situated about halfway up the head. Facial sutures distinct, the anterior run rather obliquely outwards to cut across the anterior margin, and the posterior to the hinder margin almost at the angles. Cheek-plates nearly triangular, rather wider on the outer side, posterior angles slightly produced. Thorax strongly trilobate, and composed of thirteen segments. Pleuræ faceted for rolling up. Tail about equal to a fourth of the length, wide, and sometimes truncate at the extremity; axis prominent, and composed of from eight to ten rings, lobes strongly ribbed.

In its coniform glabella with lateral furrows it resembles *Conocoryphe*; but in the position of its facial sutures, its very prominent eyes, and in its large many-ribbed and wide tail it is very distinct from that genus. The tail seems to ally it to *Dikelocephalus*; but its glabella entirely separates it from that genus. The thorax, which shows characters intermediate between *Homalonotus* and *Calymene*, is also peculiar, and unlike that of any other genus.

Neseuretus ramseyensis, spec. nov. Pl. III. figs. 7–10 & 16–22.

Head semicircular, margined, and with the angles very slightly produced. Glabella parabolic and convex, about one third of the width and rather less than two thirds of the length of the head, and indented deeply by three lateral furrows which bend backwards at their extremities; the basal furrows reach nearly to the neck-furrows, and mark off triangular lobes on either side. Eyes prominent, faceted, and placed at a distance from the glabella equal to about half its width. Cheek-plates triangular. The thorax (Pl. III. fig. 16), which evidently belongs to this species, is strongly convex; axis tapering, with sharply raised rings; pleuræ grooved and faceted, with the fulcrum situated at about a third of the distance

across, blunt at the extremities, and usually more or less incurved, or pressed against one another as if partly rolled up. Tail wide, and more or less truncate. Axis strongly raised, and composed of ten rings, the hindermost being large and pyramidal; lobes marked by seven strong ribs, grooved towards their extremities, and reaching quite to the margin. The anterior border is deeply faceted where it receives the hindmost thoracic segment. The posterior border widened out, and almost angular at the extremities. This species occurs plentifully, and is at least four or five inches in length.

Loc. Ramsey Island, and Tremanhire, near St. David's.

NESEURETUS QUADRATUS, spec. nov. Pl. III. figs. 11–13 & 23–26.

The glabella in this species is rather narrower, more angular, and less convex than in the other species. Cheeks strongly raised, and deeply punctated, and the margin in front is covered with minute spines. The punctate surface and spinous margin, however, are not specific characters, as they occur also in the larger specimens of *N. ramseyensis*.

Of the numerous tails which have been discovered, and which apparently belong to different species, I am inclined to believe that the forms figured (figs. 23–26) belong to this species. In these the axis is narrow, the lobes wide, and the hinder border more convex than in *Neseuretus ramseyensis*. This is probably the largest of the species.

Loc. Ramsey Island and Tremanhire.

NESEURETUS RECURVATUS, spec. nov. Pl. III. figs. 5 & 6.

A small species, probably not more than an inch in length. Head wider than the body, and about a third of the whole length; surrounded by a strong and wide margin, which is raised and bent backwards in front of the glabella, and slightly produced at the angles. Glabella occupying more than three fourths of the length, and nearly a third of the width of the head, parabolic and convex in shape, and indented by three pairs of furrows, which are well marked and deep. Eyes large, very prominent, situated halfway up the head, and rather near to the glabella; free cheeks triangular in shape.

Thorax composed of thirteen segments. Axis convex, wide at the upper part, and tapering gradually towards the tail; pleuræ deeply grooved, faceted, and incurved at their extremities.

Tail wide, with a strongly raised tapering axis of eight (or more) rings; lobes ribbed, and margin incurved; slightly truncate at the extremity. One of the specimens is coiled up, and another partly so. The recurved strong margin to the head, and the long parabolic glabella, distinguish this species at a glance from any of the others.

Loc. Ramsey Island and Tremanhire.

NESEURETUS? ELONGATUS, spec. nov. Pl. III. figs. 1–3.

Ovoid in shape, widest across the head. Head semicircular, and equal to about a fourth of the length. Glabella parabolic and convex, less than one third the width, and more than three fourths the length of the head. Cheeks equally convex with the glabella. Eyes

semilunar in shape, and situated more than halfway up the head; the anterior facial sutures run upward and slightly outward, the posterior bend first under the eyes, and then run obliquely outward to the inner side of the posterior angles. Thorax composed of thirteen segments; axis strongly raised, rather narrow, in width equal to rather less than two thirds the length of the pleuræ. Pleuræ deeply grooved, faceted, and blunt at the extremities; fulcrum in the upper ones situated at about a third of the distance from the axis. Tail semicircular, and margined; axis well raised, tapering, and composed of eight segments; lobes strongly ribbed at the upper part, but very faintly so posteriorly.

This may possibly belong to another genus; but as some of the characters are those of *Neseuretus*, I prefer at present to retain it under that genus.

Loc. Ramsey Island, and Tremanhire, St. David's.

NIOBE MENAPIENSIS, spec. nov. Pl. IV. figs. 1–9.

Oval in form, from 7 to 8 inches long, and about 3 inches wide. Head one third of the whole length; in shape longer than a semicircle, strongly margined, with long tapering spines reaching backwards at least two thirds of the length of the thorax. Glabella occupying one third of the width of the head, and reaching forward to the anterior margin, which it partly indents; wide in front, and posteriorly, and contracted at the middle third. It is indented by five or six faint and short furrows on each side, and by a well-marked neck-furrow. Eyes near the glabella, and placed more than halfway up the head. The anterior facial sutures run obliquely outwards, above the eyes, and cut across the margin at a distance from the glabella equal to about a third of its width. The posterior sutures curve sharply backwards, and outwards, across the posterior margin, near its middle. Thoracic axis wide, about the width of the pleuræ anteriorly, but tapering gradually backwards. Pleuræ deeply grooved, with the fulcrum situated at about one third of their length from the axis; they are strongly faceted, and very slightly pointed at their extremities.

Tail semicircular, with a very broad margin; axis moderately convex, and marked by ten distinct rings. The tip is prominent, and bluntly pointed. The sides narrow, and scored by eight furrows, which are interlined, and reach to the edge of the broad margin. (In one specimen they seem partly to run across the margin.) The margin is concentrically striate, about equally wide throughout, and raised on the inner side above the level of the surface of the lobes. Labrum long, and slightly pointed, with a strong concentric furrow near the posterior margin; the margin is wide, and indented by a pair of furrows near the tip. Width, equal to about two thirds of the length. Front much arched and about equal in width to the posterior portion.

This magnificent species is considerably larger than the *Niobe Homfrayi*, which occurs in North Wales, and differs from it in many particulars, though not sufficiently so to form a new genus. *Niobe*

Homfrayi has no spines at the angles, nor has it a strong margin to the head. The positions of the anterior and posterior ocular furrows are different in the two species; and the tail in the *Niobe Homfrayi* also has a less number of furrows, both on the axis and the lobes. The labrum, too, is wider, and has a better-defined margin.

Loc. Ramsey Island, and Tremanhire, St. David's.

Niobe solvensis, spec. nov. Pl. IV. figs. 10–16.

This is a small species, from an inch to an inch and a half in length. General shape a broad oval. Head semicircular, with posterior spines reaching backwards to about one half of the length of the thorax. Margin throughout strong, and wide at the sides, but narrowing anteriorly opposite the glabella. Glabella occupying a third of the width of the head, widest anteriorly; grooved by four or five short and faint lateral furrows, and a neck furrow. Eyes situated halfway up the head, semilunar in shape, prominent, and tolerably large. Anterior facial sutures running obliquely forwards, in front of the eyes, and the posterior backwards to cut across the hinder margin about half the distance across from the glabella to the outer edge. Body-axis broad, equally wide throughout, and moderately arched. Pleuræ as long as the width of the axis, deeply grooved, and with the fulcrum situated about a third of the distance across from the axis in the anterior ones, but further out in the hinder ones: all bluntly pointed at the ends.

Tail semicircular, with a strong margin equally wide throughout; axis well raised, tapering quickly towards the extremity, which is bluntly pointed and prominent over the inner edge of the margin, and marked by ten distinct rings. Lateral lobes wide, and marked by from six to eight ribs, the anterior ones being deep, and the hinder ones faint.

This is a much smaller and wider form than the *Niobe menapiensis*, and is easily distinguished from it by its wide thoracic axis, which is equally broad throughout, and by the wide lateral lobes of the tail. The eyes are also nearer the middle of the length of the head, and larger in proportion to the size of the species.

Loc. Ramsey Island, and Tremanhire, St. David's.

Ctenodonta menapiensis, Hicks. Pl. V. figs. 6 & 7.

C. rotunda, Hicks, Cambridge Catalogue.

Ovate in form, $\frac{1}{4}$ of an inch long by about $\frac{3}{16}$ wide. Valves well raised, beak prominent and pointed, and placed nearer to the anterior margin. Surface marked by fine concentric lines, and ventral margin fimbriated. Both ends of the shell rounded, posterior most; muscular scars strong; teeth prominent.

Loc. Ramsey Island and Tremanhire.

Ctenodonta cambriensis, Hicks. Pl. V. figs. 8 & 9.

C. elongata, Hicks, Cambridge Catalogue.

Ovate in form, but nearly equilateral, with the umbo situated almost midway between the extremities; $\frac{3}{8}$ of an inch long and rather more than $\frac{1}{8}$ in width. Shell regularly convex, and marked

by strong lines of growth near the pallial margin. Muscular scars moderately strong, the anterior being most distinct. Teeth not so prominent as in *C. menapiensis*, from which species it is at once distinguished by its subcentral umbo and nearly equilateral sides.

Loc. Ramsey Island and Tremanhire.

Palæarca Hopkinsoni, spec. nov. Pl. V. fig. 11.

Oval in form, half an inch in length, and width rather more than half the length. Hinge-line less than a third of the length. Shell convex near the beak, but flattened and spread out anteriorly. The beak does not reach quite to the cardinal margin, and is placed nearer the anterior end. Muscular scars well shown, and lines of growth tolerably distinct.

Loc. Found by Mr. J. Hopkinson, F.G.S. (after whom I have the pleasure of naming it), at Ramsey Island and St. David's.

Palæarca oboloidea, spec. nov. Pl. V. fig. 10.

Rather over a third of an inch long and nearly as broad at the widest part. Strongly convex, except near the posterior extremity, where it suddenly becomes flattened. Beak subcentral, nearer anterior extremity, and overhanging cardinal margin. Surface marked with strong lines of growth. In its subcentral beak and oboloid outline it differs materially from *P. Hopkinsoni*.

Loc. Ramsey Island and St. David's.

Glyptarca, gen. nov.

Inequilateral and strongly ventricose. Beak near anterior end, prominent, overhanging more or less the hinge-line, and pointed at the extremity. Two diverging ridges extend from the umbo to the margin, and enclose a triangular sulcus having its base at the margin, which it thereby indents. Anterior muscular impression strong, posterior less distinct. Hinge-area narrow, plate thick, with three teeth in front of the umbo. Surface strongly marked (especially near pallial margin) with concentric lines of growth. The strong diverging ridges and deep sulcus indenting the pallial margin, along with the very narrow hinge and raised and strongly produced beak, form the chief characters of this genus, and distinguish it at once from all known Silurian genera.

Glyptarca primæva, spec. nov. Pl. V. figs. 1–4.

Pear-shaped, $\frac{1}{4}$ of an inch long and about $\frac{1}{8}$ wide. Anterior extremity short, posterior long and tapering, beak prominent. Surface deeply grooved from beak to pallial margin, which is strongly indented. Lines of growth strong. Muscular scars well marked.

Loc. Ramsey Island and Tremanhire, being very plentiful at both places.

Glyptarca Lobleyi, spec. nov. Pl. V. fig. 5.

Much larger than *G. primæva*, and it is also wider at the posterior extremity. Half an inch long and about $\frac{3}{8}$ wide. Hinge-margin

very narrow. Sulcus well defined, but not as deep as in *G. primæva*, pallial margin indented, anterior and posterior edge rounded. Beak prominent, and general surface well raised. Concentric lines of growth shown, but not very strong.

I have named this species after Mr. J. Logan Lobley, F.G.S., whose tabulations of this and other classes of the Mollusca form important contributions to palæontology.

Loc. Ramsey Island and St. David's.

Davidia, gen. nov.

Ovate, umbo subcentral, nearer anterior extremity, both extremities nearly equal in width. Surface of shell raised, and almost ridged between umbo and each end near the cardinal margin. Hinge-line more or less straight, about a third of the length of the shell, and extending equally on each side of the umbo. Lines of growth strongly marked.

The subcentral umbo, equal extremities, and almost triangular shape of the shell are important characters, and sufficient to stamp it a new genus.

Davidia ornata, spec. nov. Pl. V. fig. 12.

Ovate, $\frac{7}{8}$ of an inch long and rather less than $\frac{3}{8}$ wide; beak raised, with a strong ridge extending from it to each extremity. Surface of shell marked with very strong lines of growth, posterior surface in addition covered by transverse striæ, converging obliquely from margin to umbo. Hinge-line straight.

Loc. Ramsey Island and St. David's.

Davidia plana, spec. nov. Pl. V. fig. 13.

Ovate, nearly an inch long, and rather less than half an inch wide, both extremities abruptly rounded. Beak pointed and slightly incurved. Shell evenly but strongly raised in a line from the umbo to the extremities. Hinge-line slightly convex. Lines of growth marked but not very strong. This species differs from *D. ornata* in having a less straight hinge-line, less strong lines of growth, and in the want of the transverse striæ on the posterior surface.

Loc. Ramsey Island and St. David's.

Modiolopsis ramseyensis, spec. nov. Pl. V. fig. 14.

Ovate in form, over an inch long by rather less than half an inch wide. Strongly raised along hinge-margin, and inflated. Anterior extremity short and rounded obtusely; posterior long and pointed. Beak incurved; pallial margin strongly convex. Hinge-line long. Surface covered by concentric lines of growth.

Loc. Ramsey Island and Tremanhire.

Modiolopsis Homfrayi, spec. nov. Pl. V. figs. 16 & 17.

Ovate, greatly elongated, over an inch in length by about a fourth of an inch in width. Anterior extremity short and rounded; posterior

end long, and narrowing gradually towards the extremity, which is also rounded. A moderately strong ridge strikes off from the umbo towards the posterior margin, but diminishes in strength gradually as it approaches it. Beak depressed. Hinge-line long and straight. Surface rounded and faintly marked with lines of growth, pallial margin gently curved.

Differs from *M. ramseyensis,* which it most nearly approaches, in being much narrower, less convex, and in having the posterior extremity evenly rounded.

Loc. Ramsey Island and Tremanhire.

Modiolopsis solvensis, spec. nov. Pl. V. figs. 18 & 19.

Rhomboid oval, less than half an inch long by about $\frac{3}{16}$ wide. Anterior extremity short; posterior long. A very strong ridge extends from umbo to posterior margin, and another nearly equally strong to anterior margin. Posterior edge rounded; anterior angular. Hinge-line long and straight. Shell nearly equally wide, excepting near its posterior extremity, and strongly raised along the line of the ridges. Muscular scars large and distinct. This species differs from the others in its rhomboidal shape and angular ridges.

Loc. Ramsey Island, Tremanhire near Solva, and St. David's.

Modiolopsis cambriensis, spec. nov. Pl. V. fig. 20.

Nearly oval, $\frac{3}{4}$ of an inch long, and about $\frac{3}{8}$ wide. Both extremities almost equally rounded. Beak nearer anterior margin, tolerably well raised and pointed, surface ridged from beak to posterior margin. Shell compressed. Lines of growth perceptible near margin. More oval in shape, and hinge-line shorter than in the other species.

Loc. Ramsey Island.

Bellerophon solvensis, spec. nov. Pl. III. fig. 33.

A small species, of three very gradually increasing whorls, about $\frac{1}{8}$ of an inch in diameter. Surface smooth, sides inflated. Only one specimen has been found; but this is sufficient to show that the species is new and distinct from any hitherto found in rocks of this age.

Loc. Tremanhire near Solva, and St. David's.

Bellerophon ramseyensis, spec. nov. Pl. III. figs. 30–32.

Broad, involute, with the outer whorl greatly expanded, and ridged on the back; $\frac{1}{4}$ of an inch in diameter. Surface smooth.

Loc. Ramsey Island and St. David's.

Theca Davidii, spec. nov. Pl. III. figs. 28 & 29.

Elongated and compressed. Two inches and a quarter long, and a fourth of an inch wide at the mouth. Surface marked with strong transverse lines, very slightly arched.

Loc. Ramsey Island and St. David's.

Orthoceras, sp. Pl. III. fig. 27.

The only specimen found is not sufficiently perfect to warrant a description, or the giving of a specific name.

Loc. Tremanhire near Solva, and St. David's.

Palasterina ramseyensis, spec. nov. Pl. IV. figs. 21–23.

This interesting species, the earliest starfish yet discovered in this country, was found by Mr. Lightbody of Ludlow, during our recent researches at Ramsey Island*. An inch in diameter; rays five, acute at the extremities, and enlarging gradually to about a fourth of an inch in width near the disk. Ambulacral grooves narrow, and bordered on each side by three rows of plates. The plates are closely fitted together, strongly raised; and the outer ones support some tolerably strong spines. The disk comprises about a third of the width, and is furnished throughout with strong plates. The specimens are much distorted; but they show the upper and under surfaces, and enable us to distinguish the most important characters. The length of the rays, the spines along the rays, and the comparatively narrow disk prove it to be distinct from any species hitherto published.

Loc. Ramsey Island and St. David's.

Dendrocrinus cambriensis, spec. nov. Pl. IV. figs. 17–20.

This species occurs moderately plentifully, but the specimens hitherto found are rather imperfect. I have referred it to the genus *Dendrocrinus*, as it appears to approach nearer to that than to any other genus.

Cup small, but rather wide at the base. Arms very long and many times subdivided, with a considerable distance placed between each bifurcation. The column pentagonal throughout, with strongly raised rounded edges, and enlarging gradually up to the base of the cup. Joints thin, but rather irregular in thickness.

Loc. Ramsey Island and St. David's.

EXPLANATION OF PLATES III.–V.

(Illustrative of Fossils from the Tremadoc Rocks of St. David's.)

Plate III.

Fig. 1. *Neseuretus elongatus*, gen. et spec. nov. From Ramsey Island and St David's (collection of Mr. Lightbody).
2, 3. —— ——. From Tremanhire, St. David's (the author's collection).
4. —— ——, var. *obesus*. Ramsey Island (ditto).
5, 6. —— *recurvatus*, spec. nov. Ramsey Island and Tremanhire (ditto).
7–10. —— *ramseyensis*, spec. nov. Ditto (in Mr. Homfray's and the author's collections).
11–13. —— *quadratus*, spec. nov. Ramsey Island (ditto).
14, 15. ——, free cheeks. Ditto (the author's collection).
16. —— *ramseyensis*, body and tail of. Ditto (ditto).

* Dr. Otto Torell and Mr. Linnarson had described forms of starfish which had been found in Sweden, in rocks supposed to be of the age of the Harlech group of Great Britain.

E 2

Fig. 17. *Neseuretus ramseyensis*, section showing convexity of thorax.
18–26. ——, tails of several species. Ramsey Island and Tremanhire (collections of Messrs. Homfray, Lightbody, and Hicks).
27. *Orthoceras*, sp. Tremanhire (the author's collection).
28, 29. *Theca Davidii*, spec. nov. Ramsey Island (ditto).
30–32. *Bellerophon ramseyensis*, spec. nov. Ramsey Island and Tremanhire (ditto).
33. —— *solvensis*, spec. nov. Tremanhire (ditto).

PLATE IV.

Figs. 1–9. *Niobe menapiensis*, spec. nov. From Ramsey Island and Tremanhire (collections of Messrs. Homfray, Lightbody, and Hicks).
10–16. —— *solvensis*, spec. nov. Ditto (in the author's collection).
17–20. *Dendrocrinus cambriensis*, spec. nov. Ramsey Island (in Messrs. Lightbody and Hicks's collections).
21–23. *Palasterina ramseyensis*, spec. nov. Ditto (in Mr. Lightbody's collection).

PLATE V.

Figs. 1–4. *Glyptarca primæva*, gen. et spec. nov. Ramsey Island (in the author's collection).
5. —— *Lobleyi*, spec. nov. Ditto (ditto).
6, 7. *Ctenodonta menapiensis*, spec. nov. Ditto (ditto).
8, 9. —— *cambriensis*, spec. nov. Ditto (ditto).
10. *Palæarca oboloidea*, spec. nov. Ditto (ditto).
11. —— *Hopkinsoni*, spec. nov. Ditto (in Mr. Hopkinson's collection).
12. *Davidia ornata*, gen. et spec. nov. Ditto (in the author's collection).
13. —— *plana*, spec. nov. Ditto (in Mr. Lightbody's collection).
14. *Modiolopsis ramseyensis*, spec. nov. Ditto (the author's collection).
15. —— —— (?). Ditto (ditto).
16, 17. —— *Homfrayi*, spec. nov. Ditto (collection of Messrs. Hopkinson and Hicks).
18, 19. —— *solvensis*, spec. nov. Ditto (the author's collection).
20. —— *cambriensis*, spec. nov. Ditto (ditto).

DISCUSSION.

Mr. LOBLEY commented on the importance of the discovery of so many well-marked species of Lamellibranchiata in beds of an earlier date than those in which their presence had previously been known.

Mr. H. WOODWARD agreed with the author in regarding the *Neseureti* and *Niobæ* described as presenting new forms.

Mr. HOPKINSON remarked on the similarity of the faunas of the Tremadoc and Arenig rocks to those of the Potsdam and Quebec rocks of America. With regard to the connexion between the Arenig and Llandeilo beds, he mentioned that but one or two forms of Graptolites passed from one to the other. It was, however, between the Tremadoc and Arenig rocks, if anywhere, that there appeared to be a distinct break in the series.

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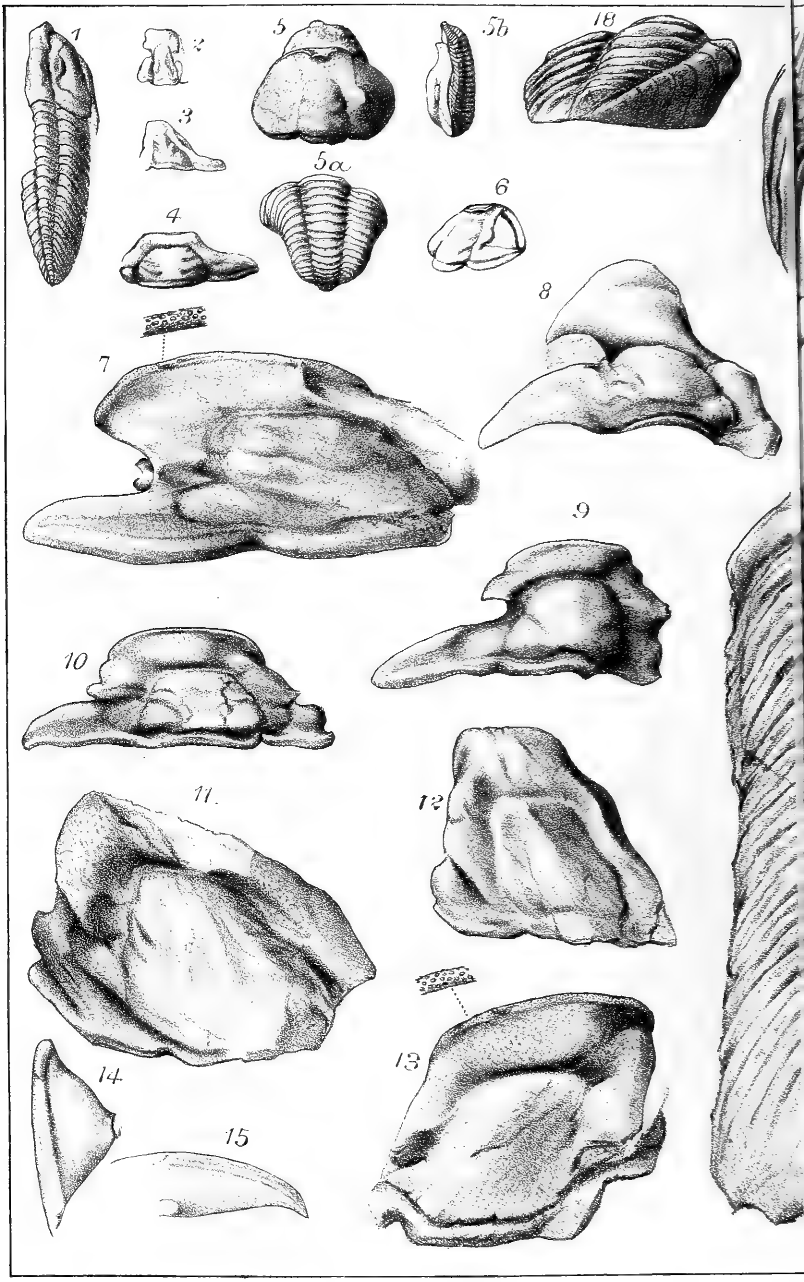
2. *On the* PHOSPHATIC NODULES *of the* CRETACEOUS ROCK *of* CAMBRIDGESHIRE. By the Rev. O. FISHER, F.G.S.

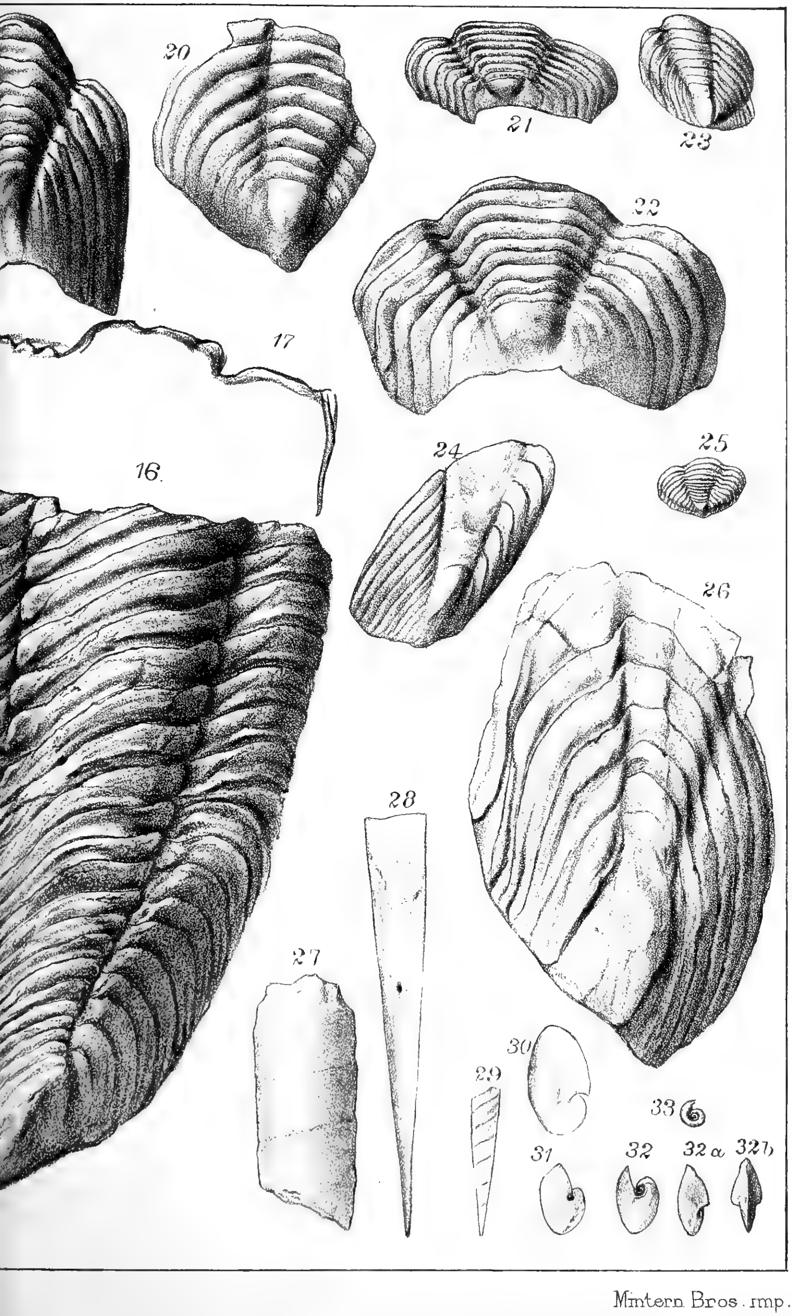
[PLATE VI.]

ON the twenty-second of January 1868, during the discussion upon Mr. Judd's paper on the Speeton Clay, I was much struck with an



C.L. Griesbach. C.H. Ford.

TREMADOC FOSS



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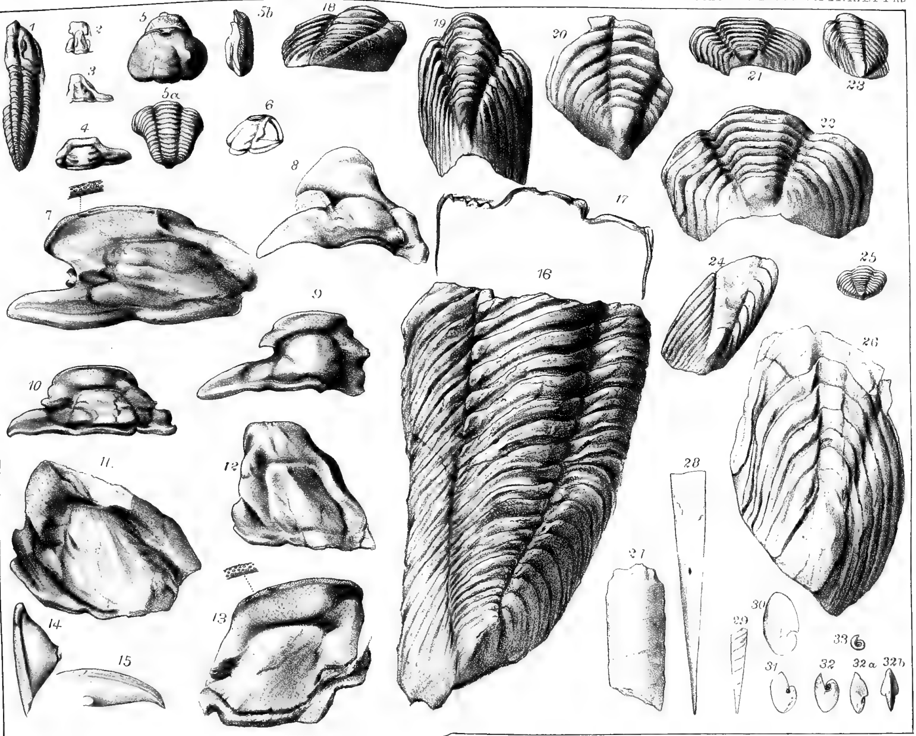

C.L. Griesbach. C.H. Ford.

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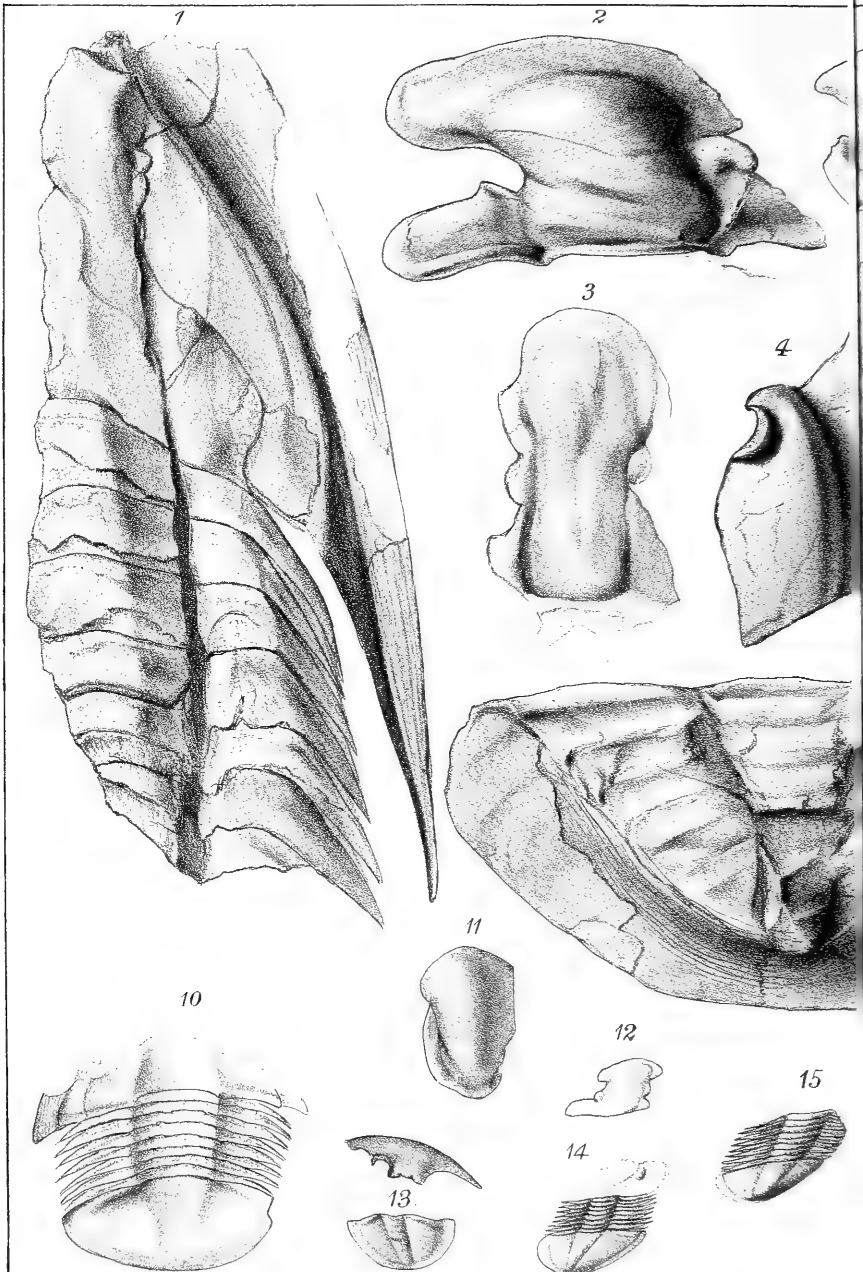
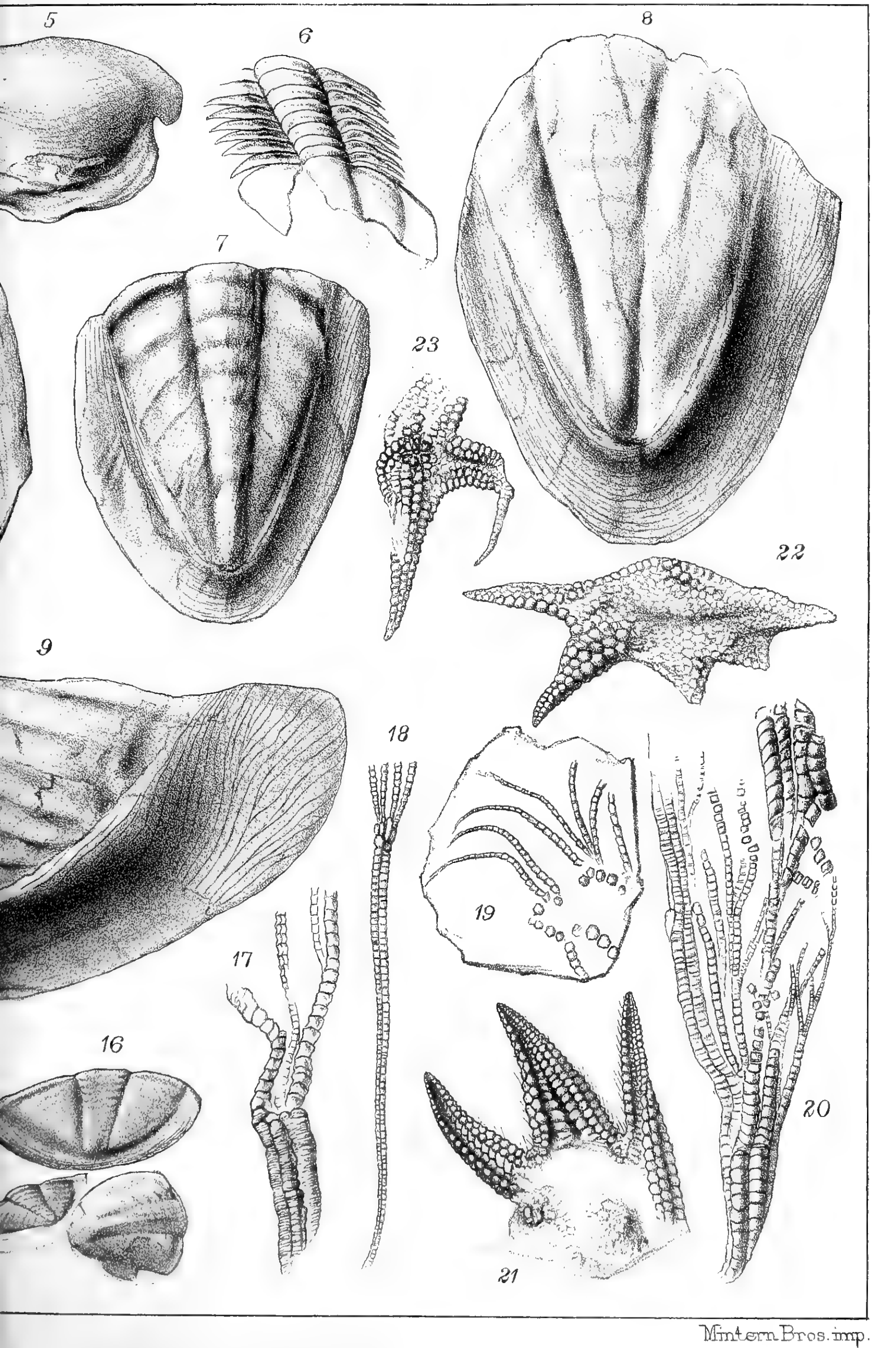


C.L.Griesbach. G.H.Ford.

TREMADOC FOS



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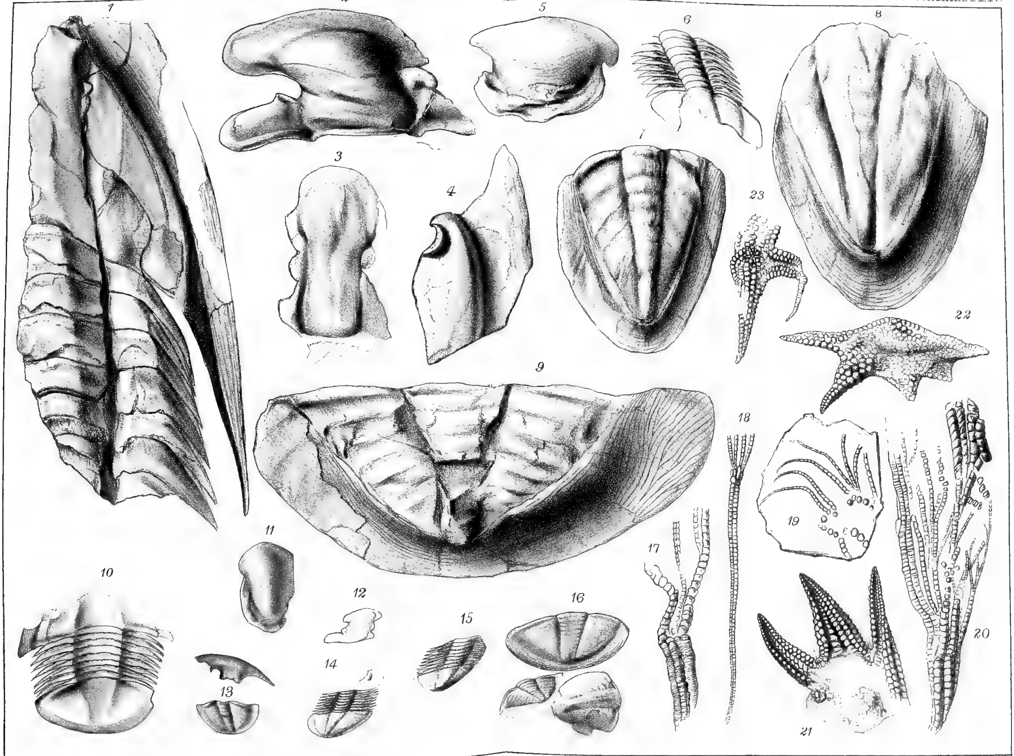

C.L. Griesbach. G.H. Ford.

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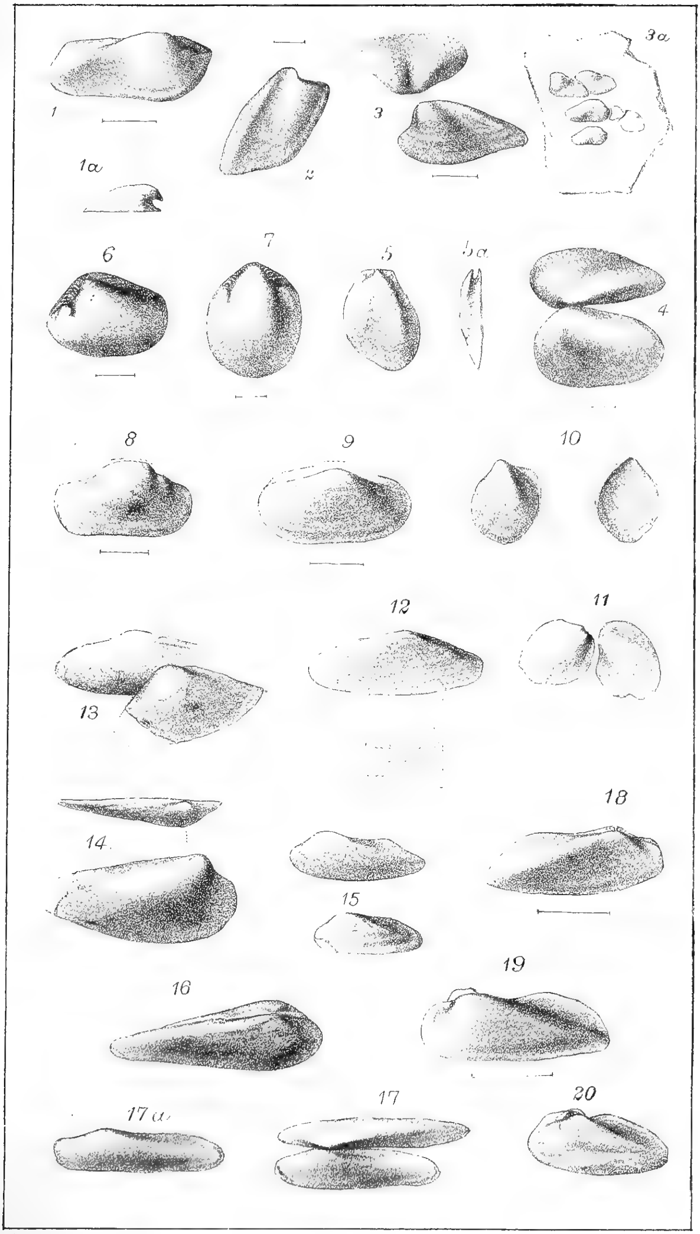

C. L. Griesbach. G. H. Ford.

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TREMADOC FOSSILS OF St DAVID'S

observation by Prof. Phillips, that our ignorance of the origin of the phosphatic nodules occurring at many horizons was a reproach to geology. A very short time afterwards the subject was proposed for the Sedgwick prize at Cambridge for 1871; but no essay was sent in. I live in the midst of the so-called Coprolite pits of Cambridgeshire, and have had my attention directed to them continuously for some time, and in May last I communicated to the Society a paper respecting them, with diagrams kindly drawn for me by Mr. Martin, of Christ's College. In consequence, however, of information which has since come to my knowledge, I was led to obtain permission to withdraw this paper, which I now offer afresh, with such alterations and additions as seem to be required.

The Cambridgeshire phosphatic nodules, as is well known, are extracted by washing from a stratum (seldom much exceeding a foot in thickness) lying at the base of the lower chalk, and resting immediately, without any passage-bed, upon the Gault. There is, however, a gradual passage upwards from the nodule-bed into the lower chalk or clunch. The average yield is about 300 tons per acre; and the nodules are worth about 50 shillings a ton. The diggers usually pay about £140 an acre for the privilege of digging, and return the land at the end of two years properly levelled and re-soiled. They follow the nodules to a depth of about 20 feet; but it scarcely pays to extract them to that depth. At some future time mining may be resorted to; but there will be some difficulties, on account of the abundance of water which is held up by the Gault, and on account of the loose texture of the clunch above.

A feature common to our nodule-bed and to those of Suffolk in the Crag, and of Potton and Wicken in the Neocomian, is that they are derivative beds. In the case of the Crag and of the Neocomian beds, fossils of several periods are mingled. This is not the case in our cretaceous nodule-bed, where all the organic fossils appear to belong to the Lower Cretaceous period.

Among the derived fossils of this deposit are the greater part of the nodules themselves; although I believe a few of them to be strictly *in situ*. All the derived specimens have *Plicatulæ* attached to them, showing that, whatever they were originally, they were hard bodies when they lay at the bottom of the Chalk ocean. Many of them are broken; and the *Plicatulæ* may frequently be seen to be attached to the broken surfaces.

Moreover the matrix which constitutes the nodule-bed gives evidence of being drifted. It contains small lumps of Chalk-marl which have fewer green grains in them than the matrix in which they are imbedded. The green grains are also evidently drifted, and dispersed in patches and layers through the deposit, having been apparently accumulated by washing from a cretaceous rock in which they were more sparsely present.

There are only certain calcareous organisms preserved in this deposit; and these are of the same kinds that we usually observe to have escaped destruction in beds which have been unfavourable to the preservation of shells. Other mollusks are found only in the con-

dition of casts, and in that case always converted into phosphate. In a few very rare instances the shelly matter has been replaced by phosphate. In the Cephalopods also the shelly substance of the septa is usually so replaced; and so likewise are the internal floors of the whorls in *Pleurotomaria*. The fossils in which the carbonate is preserved are mandibles of *Nautilus*, *Belemnites*, *Hipponyx*, *Serpula*, *Funis*, Brachiopoda, Ostreidæ, Hippuritidæ, Crustacea, Echinoderms (occasionally), and Crinoidea.

A very large proportion of the fossils, as well as most of the nodules of a dark colour, have *Plicatulæ* attached to them. But this is not the case with "associated" bones, nor with another class of phosphatic nodules, which, instead of having a dark and polished surface, present a cream-coloured and dull exterior, though internally often similar to the dark variety. It is plain that the "associated" bones must have been enveloped in the matrix before the *Plicatulæ* had time to fix upon them. And the same must have been the case with the light-coloured nodules.

It is by no means usual to find the impression of the exterior surface of a shell upon a phosphatic nodule. This renders it probable that the animal matter within the shell was the determining cause of the deposit; and in some cases at least it may be analogous to molluskite *. If it was deposited from solution in carbonated water, it is possible that the same condition of the water which enabled it to hold phosphate of lime in solution also caused it to dissolve away the shell; and because the interior walls, like the septa in the *Nautili*, would be more slowly reached, their subsequent removal might leave void spaces protected from the intrusion of matrix, and ready to be infiltrated with phosphate. Thus we can understand the internal parts of shells being mineralized while the outer parts have been removed.

Casts of the small coral *Smilotrochus* are common in phosphate. But it is always the interior of the calyx which is modelled. I have never seen a cast of the exterior. This points to the same fact, that it was the animal matter which determined the deposition of the phosphate. The grains of glauconite which abound in the matrix, and also in the indurated matter which occasionally adheres to the nodules, are never present within the matter of the brown nodules.

I have a section of a vertebra of a *Plesiosaurus* in which the osseous substance appears to be converted into the mineralized phosphate, while the canals of the bone contain glauconitic grains abundantly. This shows that they existed in a medium which was able to penetrate very fine canals, or else that they were segregated from a matrix which could do so; from their appearance I suspect the former. In either case their absence from the interior of the nodules is suggestive.

I now approach the special object I have in view—namely, to discuss the origin of the phosphatic nodules themselves.

On examining any of the heaps of these prepared for sale, it is easy to see that two varieties are especially abundant. The bulk of the collection consists partly of finger-shaped, and partly of amor-

* Mantell's 'Wonders of Geology,' p. 401.

phous lumps, varying from a very small size to pieces weighing about a quarter of a pound, though few are so large as that. The other variety, which, though numerous, is less so than the former, consists of long pieces, of such a form as would be produced by taking a cake of dough of the shape of an elongated ellipse, and folding it over a stick laid upon its longer axis. Sometimes the edges are closed, but often not so, and sometimes only partially. Frequently they appear to have been originally closed, but afterwards cracked open, owing to the contraction caused by mineralization. The hollow axis of this variety is occupied by indurated marl with grains of chlorite. These elongated subcylindrical lumps attain a larger size than the other kind, often occurring of six ounces weight or more.

These two forms are alluded to by Mr. Seeley in his paper on the rock of the Cambridge Greensand *. He supposes them to have been formed from gelatinous phosphate of lime derived from seaweeds and decaying animals, and rolled on the shore into nodules, with carbonate of lime and the materials of the strand.

Mr. Bonney, in a paper read before the Geologists' Association †, considered the nodules to be mainly of concretionary origin; for they are too pure to be regarded as clay saturated with phosphate.

Upon examining a collection of the more unusual forms of the nodules, other very distinct varieties may be distinguished. It was when examining a set of these in the Woodwardian Museum more than a year ago that I first formed the opinion, from their arranging themselves so decidedly under what seemed to be species, that I had before me true fossil forms. There was one very perplexing specimen, of a cylindrical shape, and marked on the surface somewhat after the manner of the scales of a fir-cone. Mr. Walter Keeping told me that Mr. Jesson, of Trinity College, had a specimen of this, which showed it to be the interior of the fossil known to him as *Scyphia tessellata*. And upon examining Mr. Jesson's specimen I saw that this was undoubtedly the case. I was so far confirmed in my opinion.

I have had thin sections made of a few recognized organic forms, and also of the ordinary nodules, both amorphous and cylindrical.

The same general character of the matter of which they are composed prevails in all; and the manner of their petrifaction is alike. When seen by transmitted light they are of a more or less bright amber colour, or light brown; and when placed beneath the microscope appear minutely shaded with dark ramose lines, and speckled here and there with straight or very slightly curved spicular rods, sometimes with sides parallel, sometimes like the acute accent used in printing, and occasionally pointed at both ends. Although the surface of the nodules has a porous appearance, I have not been able to trace any canals connected with the seeming pores. They are traversed by shrinkage-cracks, which appear to reveal facts of importance towards interpreting other appearances.

When such a crack commences at the surface it is usually void for a small space, the soft matrix which occupied it having been removed in the preparation of the specimen. A little further in, it

* Geol. Mag. vol. iii. p. 305. † See abstract in Geol. Mag. vol. ix. p. 144.

will be found to be filled either with clear amber-coloured phosphate or else (less commonly) with glauconite. But towards the interior it ramifies into many minute fissures, which appear black, and, losing themselves and reappearing in parallel lines with cross cracks connecting them, produce altogether a ramose structure, whose twigs are generally directed in the course of the crack.

I have noticed that, bordering their course, the phosphate is clearer and more free from the ramose shading than it is at a distance from them, and that the finer ramifications of the cracks assume very much the character, on a larger scale, of that shading. This has led me to doubt whether the shading in question may not be, at any rate partly, due to a physical cause, and not to organic structure.

These three facts, however, appear to come out clearly from the study of the cracks:—first, that phosphate continued to be deposited after the mass was already to some extent mineralized and had begun to contract from that cause, and that slightly open spaces became thus infiltrated by it; secondly, that glauconite was sometimes, but more rarely, deposited in a similar manner and in like situations, chiefly by open communication from without; and, thirdly, that the more minute vacuities within the mass were generally filled by a dark mineral, which I presume to be ferruginous.

When the nodules are dissolved in hydrochloric acid, a small residuum is left which does not commonly reveal any organic structure in the shape of siliceous spicula or otherwise. In the indurated matrix which fills the hollow axis of the cylindrical nodules a few spicula, apparently siliceous, may be here and there detected, along with the usual grains of glauconite.

In order to pass from the known, or partly known, to the unknown, I will describe the appearance of a few recognized organic forms, as seen in section under the microscope, before speaking of the ordinary nodules, the nature of which is more obscure.

The recognized organic forms, three in number, which I have examined have passed by the names of *Porospongia* and *Scyphia*. They appear to be all Ventriculites, and reveal very plainly the quadrate, reticular structure described and figured by Toulmin Smith *. And since this structure is seen equally well whether the section is horizontal or vertical, it affords a strong presumption that the true "octahedral" structure of that author is present.

An examination of these specimens, however, has led me to a somewhat different conclusion as to the nature of the fibres disposed in this quadrate arrangement from that arrived at by Mr. Smith. And this need not surprise one, because the state of preservation of the fossils is entirely different in the two cases. The most instructive of Mr. Smith's specimens, which may be seen in the British Museum, consist of Ventriculites preserved in chalk, of which the organic structure is mineralized by iron oxide. Some of these have been dissected out by the action of weak acid, and show beautifully the quadrate arrangement in minute strings of that mineral.

The bars, however, which compose the quadrate figures in our

* 'Annals & Magazine of Natural History', 1st series, vol. xx. pl. vii. fig. 9.

specimens, giving what may be very aptly called a fenestrated pattern to the entire object, appear certainly to have been tubes. The space originally occupied by the walls of the tube has usually been infiltrated by clear amber-coloured phosphate, as has happened to other wider vacuities, as already mentioned. But the central axis of the tube very commonly presents in section a black spot, although it is sometimes vacant, so that the object is pierced with numerous holes.

The minute central cavity of the tubes, filled with the dark mineral, which, as stated, also occupies the minuter cracks, appears to represent the threads of iron oxide which are alone preserved in Mr. Toulmin Smith's dissected specimens, and which led him to adopt his view of the plexus of *fibres* arranged to "prevent injury from yielding or distortion"*. A dark film of the same mineral covers the exterior of the tube-walls; and I think I can perceive minute dendritic crystals shooting from it outwards into the general mass. The section of the tube therefore, proceeding from the periphery to the centre, presents first a thin dark circle, then a wider ring of clear phosphate, and at the centre a dark spot or else a hole. Sometimes the central spot is absent. A little consideration will show that this structure is in accordance with the course of mineralization, evidenced by a study of the shrinkage-cracks, as already detailed, and points to the walls of the tube and the central hollow having been first of all incrusted by the dark mineral, and subsequently the substance of the tube removed and its place supplied by the infiltration of the phosphate. It is easy to reconcile the various appearances of the tube when the section passes parallel, or nearly parallel, to its axis consistently with the above explanation. Thus, when the section does not remove the outer crust the tube appears dark, or if a thin trace of the crust alone remains it looks like a dark brush; where the upper and lower surfaces are removed we get a clear streak bounded by thin dark lines, sometimes with and sometimes without a dark central line.

The nodes where the tubes intersect present somewhat complex appearances. Their normal character is best seen in fig. 7. The arrangement of the tubes at such a point may be roughly compared to eight rectangular hyperbolas, in three planes at right angles to each other, the branches of the curves coalescing, in sets of four, at a short distance from their common centre. Sometimes the rectangular asymptotes, which form the axis, are themselves a part of the system of tubes at the node, coalescing with the curvilinear tubes, much as a main railway line is connected with its branches at a junction. Sometimes these straight portions are wanting. The peculiar character at the node shown in fig. 4, appears to be explicable in the following way. The four round spots are the spaces included between the tubes which follow the curves and those which follow the axes. If the tubes had been mere lines, these spots would have been triangular spaces with curvilinear hypotenuses. But the great diameter of the main tubes as compared with the nodal area, and the rounding off of the angles, produce the four circular spots,

* *Loc. cit.* p. 95.

which, I conceive, were not in communication with the internal tube-spaces.

In fig. 7 modifications of this structure may be observed; for there appear to have been no tubes on the lines of the axes; and this gives the nodal area a simpler character.

It will be perceived that the above description reproduces very nearly Mr. T. Smith's "octahedral" structure.

Perhaps what I have said, together with the figures illustrating this paper, may help towards a comprehension of the affinities of the Ventriculites. Their structure is better preserved in some respects in these nodules than elsewhere. The external surfaces are better shown. And in connexion with this part of the subject I may mention what appears a singular fact. I have a specimen of so-called *Porospongia ocellata* which bears the impression of the *Ostrea carinata* at the angle formed by the auricular expansion near its hinge. The *ocelli* are entirely confined to the surface of contact, and upon the other surface there are none apparent.

Spicula are scattered throughout the mass of these specimens, especially in *P. ocellata*. They have the character of sponge-spicula, but appear not to be siliceous; they are for the most part straight, and tapering towards one end.

I now pass to the consideration of the ordinary nodules, which are obtained by the ton weight, whilst those just described are quite rare fossils.

Upon a close examination of their surface (fig. 8) it will be perceived that they have a peculiar granulated surface like that of leather, and that they are constantly wrinkled in places, as if by the contraction of an integument. These wrinkles are more numerous and marked wherever the surface is somewhat pitted or depressed, while protuberant parts are often smooth. It is not easy to speak with certainty; but the surface seems to be minutely porous.

The wrinkles do not follow any determinate direction, although in the digit-like forms they are usually more or less transverse to the length. The constancy of these characters of the surface, and their general shape according with the idea of growth, renders it certain, in my opinion, that these nodules were organic bodies. But it is not easy to determine their affinities.

My original idea was that they were sponges. However, upon submitting some thin sections of them to Dr. Bowerbank for his opinion, he informed me that he could not perceive that they exhibited any traces of sponge-structure. This led me to compare them with the *Alcyonium digitatum*. When this polypidom dies, it parts with some of the water which distends it, and the integument becomes wrinkled and roughened with irregular papillæ, which cover the cells of the polyps. It is not easy to obtain a specimen of the recent zoophyte unaltered in shape, because, when it parts with the water contained in it, it takes the form of any surface with which it is in contact. But, out of many specimens kindly sent to me by Mr. Damon, I have so far succeeded in making some plaster casts of the recent zoophyte, that, after being coloured, their close resemblance to the

fossils may be appreciated. The recent *Alcyonium* attaches itself to oyster-shells, or other bodies, by a disk, which retains the impress of the nidus. But it is easily removed from its attachment when dead. I am persuaded that when a perfect nodule is examined, a disk of attachment can often be detected, at one end, in the digit-like forms, as if they had grown upon a shell, and in the amorphous nodules at some other part, giving in this case the appearance of the attachment having been effected to sticks or seaweed. It appears to me that the two varieties of form are quite in accordance with the modes of growth which would result from these two modes of attachment.

Nodules of the second more common type appear to be incrusting forms, whether sponges or Alcyonaria. They appear to have grown upon an axis of sea-weed or of wood; for the internal cavity does not seem to have been a cloaca, because it passes from end to end, and the specimens are not funnel-shaped, the two extremities of the hollow cylinders being similar, and finished off alike with a cushion-like rounded edge, and frequently the cylinder is not complete. Specimens of elongated masses are not uncommon which look, at first sight, like pieces of fossil wood, being composed of a bundle of longitudinal fibres, not ill corresponding with the internal longitudinal canals of *Alcyonium digitatum* described by Johnston, and figured by him*. These, if Alcyonaria, may be individuals which have become mineralized after the destruction of their integument.

Thus these two forms appear to fulfil the conditions described by Johnston as externally characterizing the genus *Alcyonium*. "Polype-mass lobed, or incrusting, spongious, the skin coriaceous, marked with stellated pores;" to which description is added for *A. digitatum* "the skin somewhat wrinkled, studded over with stellated pores even with the surface"†. The "interior of the *Alcyonium* is gelatinous, netted with tubular fibres, and perforated with longitudinal canals terminating in the polyp-cells, which are subcutaneous and scattered." In the *A. digitatum*‡ "the space between the tubes is occupied by loose fibrous network," and "the interstices of the whole are filled with transparent gelatine, in which numerous crystalline irregular spicula lie immersed." These spicula are calcareous.

An examination of sections of these nodules does not assist us much in their determination. They are highly mineralized; for they exhibit wide shrinkage-cracks. And of the specimens I have had cut, those which promised to be most sound from the integrity of the outer surface, have turned out most cracked inside. This is exactly what happens in the case of ordinary septaria.

Where so much contraction has occurred, amounting to perhaps one third of the area of the section, it is not surprising that delicate structure should have been obliterated. The features that can be made out appear to me to be the following:—

The general mass is pervaded in many parts by a minute shading

* Johnston's 'Zoophytes,' 2nd edition, vol. i. p. 176.
† *Ibid.* p. 174. ‡ *Ibid.* p. 176.

in a mossy or dendritic fashion; but, as I have already said, there are reasons for doubting that this shading had an organic origin. In some specimens canals may be seen, some of them open, and some of them filled with phosphate. They are numerous, but show no definite arrangement. The minute dark spicular-looking bodies already described (see fig. 9) are always present, and usually much broken. They appear to be more abundant towards the external surface; and in some cases the structure there seems to be of a more definite character for a certain small thickness. But whether this arises from that part being better-preserved because less affected by contraction, or whether the constitution of it was originally different—or whether the difference is apparent only, arising from a different amount of mineralization, it is not easy to decide.

On the whole a microscopical examination of these bodies rather recalls me, so far, to my original opinion that they were sponges; while at the same time it must be admitted that in their external appearance they much resemble Alcyonaria. Contrary, however, to all the views, as far as I know, published previously to the first reading of this paper, I am decidedly disposed to give it as my opinion that the ordinary phosphatic nodules were originally organic bodies*.

If these organisms had contained siliceous spicula, they might be expected to have been preserved entire; but if they contained calcareous spicula these will probably have been transmuted into phosphate, and, being imbedded in a ground of the same, many of them will have disappeared by being blended with the general mass, and others will be only partially distinguishable. Such partial obliteration has occurred to the septa of a *Nautilus* of which I possess a section.

The phosphatic casts of Cephalopods and Gasteropods, when sliced and placed under the microscope, present a somewhat similar appearance to the nodules. But they do not, as far as I can observe, contain any spicula. I do not offer any opinion upon them, further than that I believe them to be derived from organic matter, and to be either fossil *Alcyonia*, sponges, or molluskite. A point strongly in favour of this view is that the phosphatic matter appears to be universally adherent to the interior of the shell; and although it sometimes protrudes beyond the mouth of the shell, or out of the cavity of an *Echinus*, we do not find it moulded upon the exterior of the shell. The same may be said of the Crustacea.

If such organisms as these have been copiously preserved in this deposit, we may expect to find the Tunicata, Holothurida, and such like bodies, also phosphatized. Indeed I believe that a palæontologist would find a wide field of interest in examining these nodules. But in order to success he must search the pits himself, and select his specimens from the unwashed stuff, because the trituration of the washing-trough, or "mill," effectually effaces all delicate external markings.

* I desire to bear my testimony to the satisfactory results obtained by Mr. Sollas, who has submitted a larger number of these fossils to microscopical examination than I have done, and has determined several species to be sponges.

The segregation of minerals is, I suppose, an obscure subject; and I cannot explain the process in the case before us. Dialysis seems to require a passage of the depositing fluid across the dialyzer from a region of greater to one of less saturation; and it is not easy to see how this could happen in the case of an organism immersed in ooze, or in the ocean. Subaerial water, percolating through strata, and charged with mineral matters in its progress, might perhaps more easily act in this manner. But there does not seem to be any cause to doubt that the phosphate of lime was precipitated from solution in water charged with carbonic acid, it having been previously secreted by animal agency. Even yet it subsists in the chalky matrix to so great an extent as to be appreciable, as I am informed by Mr. Liversedge, of Christ's College, who has examined it for me.

Analyses of the glauconite grains by Professor Liveing, and of the phosphatic nodules by Dr. A. Voelcker, will be found in Mr. Seeley's paper before referred to*.

When the coprolitic bed is within three feet, or thereabouts, of the top of the ground, the nodules become weathered, eventually receiving a uniform greyish colour upon the surface. This weathering commences with dendritic whitish markings slightly eating into the substance of the phosphate; probably they are caused by the decomposition of rootlets in contact with the nodules, which have given off carbonic acid, and dissolved the mineral where they have touched it. That these curious markings are not the result of any peculiar internal organization of the substance of the nodules, is shown by the fact that exactly similar markings occur on sharks' teeth under like conditions.

The phosphatic nodules of a dark and somewhat lustrous surface, as already stated, usually have *Plicatulæ* attached to them. Their being found adhering to broken surfaces and over shrinkage-cracks shows that the nodules were previously mineralized, and are consequently derivative. But such of the nodules as have a light-coloured and dull surface have no *Plicatulæ* upon them. These latter I take to be indigenous to the deposit. Where nodules adhere to bones, the *Plicatulæ* sometimes occur attached partly to each.

Many of the nodules occur in a fragmentary state, broken up into small angular fragments, evidently by shrinkage-cracks having formed in them as in septaria; and these cracks do not appear to have been occupied by crystallized calcite, but by indurated matrix. These changes must all have occurred before the formation of the deposit.

The indurated matrix which fills the axes of the cylindrical nodules was in all probability introduced while the fossils were in their original *gisement*.

Hence we gain a clue to the derivation of the fossils of the thin crowded layer of the so-called Upper Greensand of Cambridgeshire. They seem to have been washed out of a calcareous marl similar in character to the marl which lies above it. In short, the nodule-bed is a condensation of the "Chalk-marl with glauconite grains."

* Geol. Mag. vol. iii. pp. 305, 306.

I believe this to be a much more probable account of the derivation of these nodules than that which attributes them to denudation of the Gault. It is true that nodules of a somewhat similar character are found below in the Gault; and I have no doubt that their origin is likewise organic; but they are for the most part much smaller—dwarfed, as if the muddy waters of the Gault sea did not suit them; they are also very sparsely scattered in the clay.

In the history of these nodules we have an instance of what is taught us by many similar facts in geology, namely the rapidity with which petrification has taken place—so that we find fossils, after having been completely mineralized, redeposited in another stratum of what we are in the habit of calling the same deposit.

When we compare the Lower Cretaceous beds of this district with those of the west and south of England, we are struck by the absence of that great arenaceous deposit, the Upper Greensand, while the lower beds of the Chalk in both areas are extremely alike. We find in Hampshire and in Dorsetshire a thin band very similar to our phosphatic bed, which, like it, passes upwards into a Chalk-marl with glauconite grains. But the point of difference is, that here the nodule-bed rests upon the Gault, whereas there we have the great arenaceous deposit intervening. In both districts this thin band appears to represent a long period. It is probable that it is the washed remnant of a glauconitic marl-deposit in both districts.

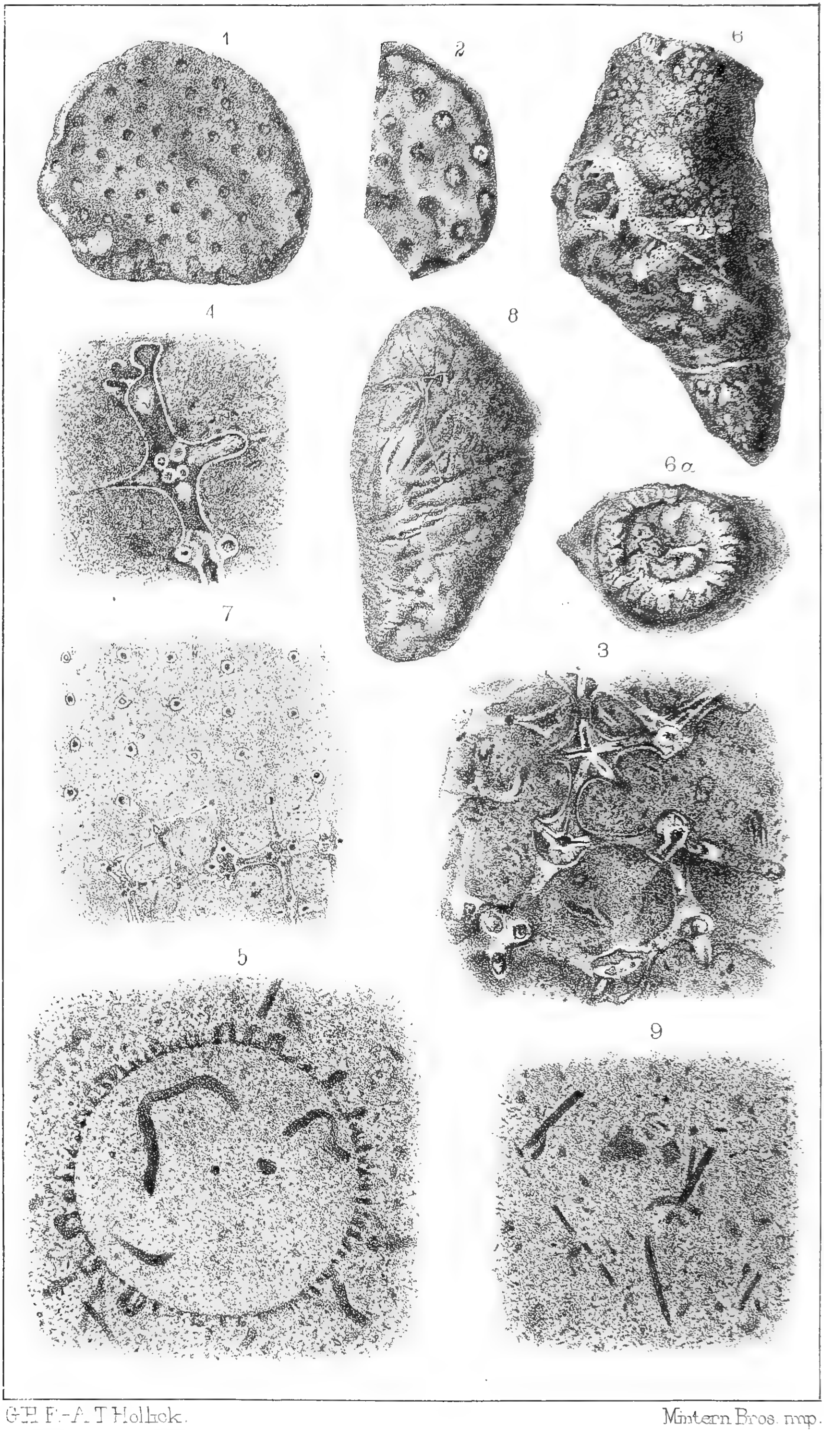
We have, then, to account for the absence of the arenaceous greensand in the Eastern Counties. It is probably due to the ridge of old rocks beneath the London area, which shut off the early Cretaceous sea to the north of it from those south-western lands which yielded the sandy spoils.

And if it be not going beyond the scope of this paper, I may mention that I suspect a similar cause to have produced the marked change between the Lower Cretaceous rocks in Cambridgeshire and the corresponding beds in Norfolk and Lincolnshire.

A glance at a geological map of England will show the outcrop of the secondary rocks thereabouts making a semicircular sweep, having the old rocks of Charnwood forest in its centre. We have also a Palæozoic slaty rock within about a thousand feet of the surface at Harwich.

If those two points be joined by a line curving slightly northward, just parallel to the axis of the Weald, such line will represent the direction of the slight elevation to which the curvature of the outcrop of the Secondary rocks is due, and will pass through the area where the character of the Lower Cretaceous rocks changes from nodule-bed and Gault into Red Chalk. A second Palæozoic ridge following that direction would account for this change*; and we might look to the Trias, which on every side of Charnwood abuts upon the Cambrian rocks, to have furnished the ochreous deposit giving rise to the Red Chalk.

* Several of the erratic pebbles of the phosphate-bed may be matched by rocks from Charnwood. In Mr. Jesson's collection I have seen pebbles of a very peculiar, greenish, flinty slate which occurs *in situ* near Whitwick.



G. H. F. - A. T. Hollick.

Mintern Bros. imp.

CAMBRIDGE PHOSPHATIC NODULES

EXPLANATION OF PLATE VI.

Fig. 1. A small specimen of *Porospongia ocellata*, from the Woodwardian Museum, Cambridge.

2. Half a similar specimen.

These two specimens show no apertures on the opposite surfaces.

3. Quadrate reticular structure as seen in a horizontal section of part of the removed portion of the specimen fig. 2. The area figured has the reticulation less regularly quadrate than usual. Magnified 60 diameters.

4. A view of a node of the preceding, with the two adjoining nodes less distinctly displayed on account of the obliquity of the plane of section. Magnified 60 diameters.

5. A view of one out of several such bodies which occur in the slice from which figs. 3 and 4 are taken. They appear to have been spherical. Are they reproductive germs? Magnified 250 diameters.

6. A cyathiform specimen having smaller apertures. The regularity of the form is obscured by the adhesion of a mass of phosphate.

The lower extremity is imperforate, and tapers off regularly, the apertures extending to the point. This agrees with Mr. Toulmin Smith's description of that part in the *Ventriculidæ* (Ann. & Mag. Nat. Hist. vol. xx. p. 91, 1847).

6 *a*. The upper extremity of the same specimen.

7. Quadrate reticular structure as seen in a transverse slice of a specimen of the same kind as the last. The plane of section passes through a plane of nodes at the bottom of the figure, but avoids them in the upper part, there cutting only the intermediate canals. Magnified 25 diameters.

The slice, of which a part is figured, was taken at about ½ an inch from the upper extremity of a specimen of the same size as fig. 6, and proves the central cavity to have been narrow. But its condition is unfavourable for taking an exact measurement.

8. External aspect of an ordinary nodule, showing the wrinkled surface and some shrinkage-cracks. A surface of attachment is on the further side of the specimen.

9. A portion of a slice taken from an ordinary nodule near the exterior, showing spicular bodies. Magnified 35 diameters.

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3. *On the* VENTRICULITÆ *of the* CAMBRIDGE UPPER GREENSAND. By W. JOHNSON SOLLAS, Esq., Associate of the Royal School of Mines, London; Scholar of St. John's College, Cambridge.

(Communicated by the Rev. T. G. Bonney, M.A., F.G.S.)

[Abridged.]

OF the sponges found in the Upper Greensand of Cambridge, certain forms, *Scyphia*, *Porospongia*, and various hitherto unnamed species, are shown by this investigation to belong to the genus *Ventriculites*. The character which is stated by Toulmin Smith* to be absolutely diagnostic of the Ventriculidæ is the cubic arrangement of the fibres supported at the angles by octahedral stays; and on making sections of the above sponges this structure may at once be distinguished under the microscope. It appears in the most favourable sections as a square or rectangular reticulation, composed of a number of crosses, the arms of which represent four of the six rays of the hexradiate elements of which, on the modern view of

* Toulmin Smith, 'Ann. & Mag. Nat. Hist.' vol. xx. 1847, and 2nd ser. vol. i.

Ventriculite-structure, the skeleton is considered to be composed. On examining one of the above crosses, it is seen that its radii start from their common centre as very fine filaments indeed; but after pursuing their course for a quarter of their entire length, they undergo a sudden enlargement in diameter, and continue uniformly of this increased size to their terminal anastomosis. At the point of rather abrupt change in the diameter of the radius two other fibres are given off, one on each side, which pass backwards at an angle of about 45°, to join similar fibres similarly passing from the other arms of the cross; in this manner, about the centre of the cross under consideration, is formed a rough square, which represents the octahedral stays in section (fig. 1). This description applies equally to the sections figured of Toulmin Smith's Ventriculites in flint, and to those of the Cambridge forms in phosphatic material; and consequently, according to the admitted diagnosis of the family, there can be no doubt that our Cambridge fossils must be included in the same group with those of the Chalk, whilst a detailed examination has enabled me to identify, from our formation, forms belonging to some four of T. Smith's species; and there are others in my possession which I hope to determine when time allows.

Modes of Fossilization.—The fibre of our Cambridge Ventriculites presents itself under four different conditions of preservation.

(i.) Simple opaque fibres, of which the distal radial fibres are from $\frac{1}{1250}''$ to $\frac{1}{1000}''$ in diameter. Generally insoluble in hydrochloric acid.

(ii.) The simple fibre of No. i. is frequently surrounded by transparent colourless walls, from $\frac{1}{3000}''$ to $\frac{1}{2000}''$ in thickness, and generally well defined on their inner and outer circumferences. They give no colours with polarized light, but shine brightly on the dark ground produced by crossed prisms. Under a high power they seem to be made up of a number of crystals placed perpendicularly to the surface on which they are set. In hydrochloric acid they dissolve, but not so readily as the surrounding coprolite. The opaque fibre they enclose is next to insoluble in hydrochloric acid; it remains as an opaque yellowish-brown rod after the colourless walls have been altogether dissolved away.

(iii.) The opaque fibre of No. ii. has entirely disappeared, leaving only the colourless walls which surrounded it; these now form a cylindrical tube, measuring usually from $\frac{1}{600}''$ to $\frac{1}{400}''$ in diameter in the distal radii, and having a central hollow cavity of from $\frac{1}{1250}''$ to $\frac{1}{600}''$ diameter (fig. 1).

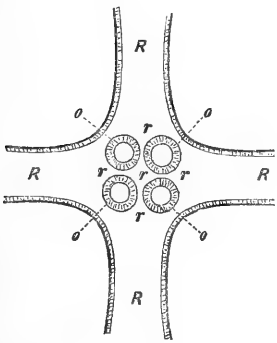
(iv.) The colourless walls and opaque fibre have both disappeared, and their place is occupied by a finely granular material, appearing in section as a broad band, of variable diameter, frequently from $\frac{1}{500}''$ to $\frac{1}{400}''$ across, generally of a brown colour, but sometimes pale green from infiltrated glauconite. With polarized light it appears strongly luminous on the dark ground produced by crossed prisms. In hydrochloric acid it is far less soluble than the adjacent coprolite.

In some sections of the Cambridge Ventriculites, simple opaque

spherical bodies are found from $\frac{1}{200}''$ to $\frac{1}{400}''$ diameter, which agree in their mineral characters with the opaque yellowish-brown fibre of No. ii.

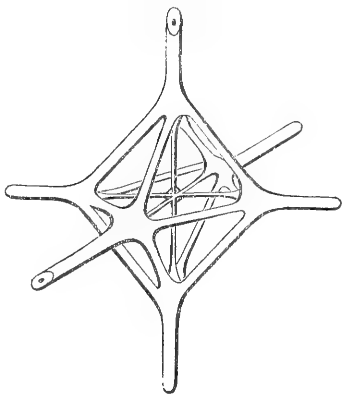
The Hexaradiate Elements.—The Ventriculite skeleton is formed by the regular anastomosis of a number of hexaradiate elements, each one of which consists of six radial fibres, apparently tubular, diverging from a common centre at right angles to each other. To the end of the first quarter of their course the fibres are of the most microscopic diameter; but they then suddenly expand, their diameter becomes many times greater, and continues so to the end of their entire course, where they open into the similar radii of surrounding elements. At their point of expansion they give off four fibres of a diameter of about $\frac{1}{2500}''$, which pass backwards at an angle of about 45° to join similar fibres given off by the other arms of the same element, so as to form a skeleton octahedron about the common centre (fig. 2). This is the typical structure of the hexaradiate

Fig. 1.



R, radii.
r, interior radii.
o, spaces.

Fig. 2.



elements. As in the Vitrea, however, abnormalities occur, the elements sometimes becoming pseudo-heptaradiate (fig. 3), and sometimes apparently triradiate. The additional ray of the heptaradiates is prolonged merely from one of the octahedral fibres, and does not start from the common centre of the six normal rays. The triradiates also have nothing in common with the hexaradiate elements.

Combination of the Hexaradiate Elements.—Considering one of these elements, it will be seen that each of its four horizontal radii is freely continuous in the same straight line with a horizontal radius furnished to it by one of four other elements symmetrically disposed in the same plane around it; each of the vertical radii is continuous in the same way with a vertical radius derived from each of two other elements, one placed above and the other below it: all the

radii are normally of the same length; and consequently the centres of these hexaradiate elements are all equally distant ($\frac{1}{100}''$) from the centre of the element they surround. Thus each hexaradiate element is continuous with six other hexaradiate elements symmetrically arranged around it; and these six elements are similarly continuous with other elements surrounding them in turn, and so on till the limiting surfaces of the organism are reached. Thus a vertical radius is continued upwards as a vertical fibre, and a horizontal radius is similarly continued as a horizontal fibre; and in this way all the radii fall into three groups of more or less parallel fibres: (i.) vertical or longitudinal fibres, composed of a series of vertical radii, radiate from the base of the ventriculite upwards, diverging as they go in gentle curves to the outer wall; (ii. and iii.) horizontal radii in two series, one group concentric with the cloaca of the sponge, and the other radiating from it. The centres of the hexaradiate elements are the points where the fibres of these three series intersect.

This typical arrangement of the elements is subject to very numerous variations.

(i.) One ray from an element, instead of diverging from its fellows at right angles, bends away some 45° from its normal course to fuse with the similarly inclined radius of an adjoining element (fig. 4).

Fig. 3.

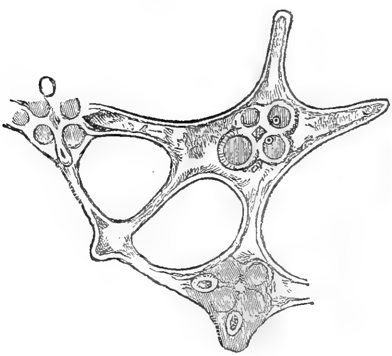
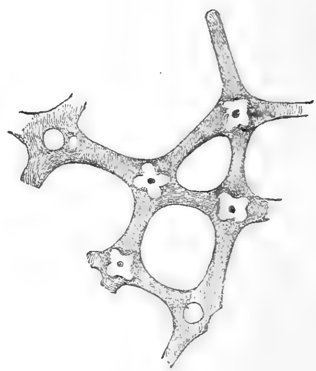


Fig. 4.



(ii.) Two parallel rays from a pair of elements combine with two other rays, furnished not from *two* other elements, as they should be normally, but from a single element alone. By these abnormalities (i. and ii.) the radii join to form a triangle instead of the ordinary rectangle. In this way is produced a change of direction in the course of the fibres.

(iii.) In a series of pairs of elements, the fibres between the centres of succeeding elements gradually become longer, till, at the third or fourth pair from the point at which the increase in length commenced, an additional element is introduced, to preserve the normal distance between the diverging series.

(iv.) On the fibre between two elements at the ordinary distance from each other, the centre of an apparently superfluous element unexpectedly appears. Of its four radii seen in the section, two of course are parts of the fibre on which the centre occurs; the other two normally have no radii with which they can combine, and as a consequence they bend away in opposite directions at about 45° from their fellows, and open into the octahedral fibres of adjacent hexradiate elements (fig. 5). Besides these, other variations occur (fig. 6).

Fig. 5.

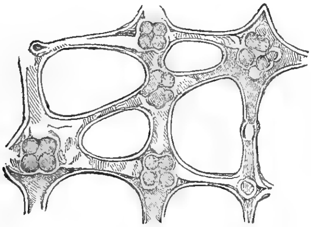
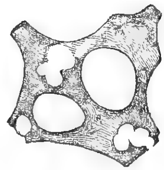


Fig. 6.



Spicules.—Though siliceous spicules are well preserved in some flints and coprolites, yet a careful examination has failed to reveal their presence in silicified ventriculites (T. Smith) or in phosphatized ones. For all this the Ventriculites may have been spiculate sponges; in a section of a *Brachiolites*, and in one of *V. tessellatus*, I have found simple acerate spicules, with which were associated one or two hexaradiate ones; possibly, however, these may have been washed in from the sea-bed during fossilization.

Identification of Species.

i. Ventriculites tessellatus (Toulmin Smith); *Scyphia tessellata* (Seeley); *Spongia texturata* (Quenstedt).

Quenstedt's figure* of this species is an excellent one; it is taken from a specimen from the Weisse Jura, and accurately reproduces the Cambridge form. Quenstedt refers *Scyphia texturata* and *S. parallela* (Goldfuss) to the same species†, as well as *Alcyonites texturatus* (Schlotheim‡ and Parkinson §). This latter identification appears to me very questionable, Parkinson's figure more nearly representing *Ventriculites quincuncialis* than *V. tessellatus.*

In the Royal College of Surgeons is a specimen from the Jurassic of Württemberg, labelled by Prof. Morris, *Ventriculites texata* (Münster), which is in every respect a fac-simile of our Cambridge species; and I believe *S. tessellata* (Seeley), *S. texturata* (Quenstedt), and *V. texata* (Münster) are identical with *V. tessellatus* (T. Smith).

The following is a description of our Greensand *Ventriculites tessel-*

* Der Jura, Quenstedt, tab. 83. fig. 7, p. 683.

† Petref. Germ., Goldfuss, tab. 2. fig. 9, tab. 3. fig. 3.

‡ Petref., Schlotheim, p. 373.

§ Parkinson, 'Organic remains,' tab. 10. fig. 12.

latus:—*Form* conoidal or cylindro-conoidal, a thick outer wall surrounding a central hollow cavity. *Wall* more or less rounded off to an edge, sometimes produced at the circumference of the cormostome into a little rim, reminding one somewhat of the beard of *Holtenia* in the same position. *External surface*: most exterior is a surface of fine texture, regularly marked with oblong rectangular depressions, which have well-defined edges, and are arranged not quincuncially but in a quaternary series; these cease on the upper surface of the wall, around the cormostome; the surface intervening between the oblong depressions and that surrounding the cormostome is pitted with innumerable minute punctations, corresponding to the hexaradiate elements. When the exterior surface is worn away, or when a section is made parallel to the sides of the wall, a system of irregularly winding cavities is exposed, which preserve more or less a circumferential direction; they arise from the suppression of a variable number of the vertical partitions between the oblong openings; internally they communicate with the great central cavity, or excurrent canal, by apertures which are well seen in a vertical section. When from the top of the wall its plain surface is removed, the canals beneath are revealed.

This species is very rare in the chalk, but in the Upper Greensand is by no means uncommon.

ii. V. MAMMILLARIS (T. Smith).

No doubt can exist regarding the identity of our Cambridge *Scyphia* with this species; the simple and regular inner plaits of the chalk specimens are distinctly evident in our Greensand forms, as also are the large and hollow bosses raised on the outer surface at regular intervals.

iii. V. QUINCUNCIALIS (T. Smith).

The Ventriculite arrangement of fibre is not so plainly exhibited in sections of this form as one could wish; but I think there is sufficient evidence to refer it to *Ventriculites*; and in its external characters, which are well preserved, it does not differ in the slightest detail from *V. quincuncialis* (T. Smith).

iv. V. CAVATUS (T. Smith); *Porospongia ocellata* (Seeley).

A section of *P. ocellata* reveals the Ventriculite structure in all its details; in some genus of the Ventriculidæ it must consequently be placed; and from the thickness of its walls, the somewhat quincuncial arrangement of the oscula on its surface, and its general agreement with T. Smith's figures and description, I believe it to be a true Ventriculite, and different in no essential respect from *V. cavatus* (T. Smith). Its oscula vary considerably in size in different specimens; in one in my possession they are more than twice the diameter of those in another: this has been noticed as a peculiarity in the chalk forms of *V. cavatus*. The walls seem to be perforate.

Toulmin Smith proposes a classification of the chalk beds into upper, middle, and lower, based on the genera of Ventriculidæ they

contain. He states that while Brachiolites are found in the Lower Chalk and Upper Greensand, Ventriculites are confined to the Upper Chalk alone, occurring very doubtfully in the Middle Chalk, if at all; the identifications in this paper, however, show that the genus *Ventriculites* not only is not confined to the Upper Chalk, but is found abundantly as low as the Gault in England (for these Upper Greensand specimens are derived from the Gault) and still lower in the White Jura of the Continent. The occurrence of Ventriculites in the Oolitic formation does not tend to strengthen the affinities of the Chalk with our own times.

The analogy I drew in a former paper between the flints of the chalk and the coprolites of the Gault, receives illustration from these newly discovered Ventriculites; for precisely as the silicified Ventriculites are closely associated with obscure siliceous nodules or flints, and, with them, are instances of that remarkable fact the silicification of highly decomposable animal matter; so the phosphatic Ventriculites are closely associated with obscure phosphatic nodules or coprolites, and, with them, are striking examples of the phosphatization of soft-bodied animals.

For the valuable assistance I have constantly received throughout the preparation of this paper, my thanks are due and heartily tendered to the Rev. Mr. Bonney, of St. John's College. I have also much pleasure in thanking Mr. Jukes Browne (St. John's) and Mr. Jesson (Trin. Coll.), to whom I am indebted for many interesting specimens of our Cambridge Ventriculites.

Discussion.

Mr. J. F. Walker was not prepared to admit that all phosphatic nodules had been organized bodies, inasmuch as most of the fossil shells in the deposit were found filled with phosphatic mud of the same nature as the nodules.

Mr. Charlesworth also disputed the organic origin of the amorphous coprolites—and pointed out the analogies between the so-called coprolites of the Crag and those of the Upper Greensand, and the flints of the Chalk. He cited Ehrenberg as of opinion that the latter were masses of fossilized infusoria, while Dr. Bowerbank maintained that they were merely fossil sponges; and he drew the deduction that caution was necessary in accepting any theory as to the origin of the phosphatic nodules.

Mr. Seeley was not entirely in accord with Mr. Fisher as to the number of forms assumed by the phosphatic nodules. There were some that resembled common septaria; and in many cases the original form, especially in the case of the presumed Ventriculites, had been much modified by rolling on the sea-bottom. In support of the view of the sponge-origin of some of the nodules, he exhibited some of the modern forms of sponges enveloping different objects in the same manner as the phosphatic matter included shells and other fossils. Some of the *Porospongiæ* in the Woodwardian Museum were, he said, not phosphatic, but calcareous fossils; and he thought some mistake had been made by Mr. Sollas in alluding to these specimens.

The phosphatic masses were frequently drilled and filled with glauconite and other matter. He doubted the ventriculite origin of many of the nodules, and pointed out that the so-called Ventriculites were in reality *Ocellariæ*.

Mr. H. Woodward mentioned that a similar structure to that described in the Ventriculites had been discovered by Mr. Kent in a modern siliceous sponge, and observed on the similarity in some respects between ventriculite structure and that of *Euplectella aspergillum*. He thought that, whatever might be the origin of some of the chalk-flints and phosphatic nodules, it was unsafe to refer the whole of them to the growth of sponges.

Mr. Fisher, in reply, did not agree with some of the speakers in considering that various organic remains were often found imbedded in coprolitic matter, though many were filled or partially covered with it. There was, he thought, a difference between the coprolites of the Crag and those of the Greensand; the surface of the great bulk of the latter had to his eye an unmistakably organic appearance. In some cases he thought they might have been allied to Alcyonaria. He did not agree with Mr. Seeley as to many of them being in a rolled condition.

Mr. Sollas stated that some of the coprolites contained siliceous *Xanthidia* and Polycystina uninjured, which afforded an argument against regarding the Ventriculites as having originally had a siliceous skeleton which had subsequently been replaced by phosphate of lime. He had also found well-preserved siliceous spicules in the coprolites. The forms, though numerous, were well defined and susceptible of classification, which he had attempted to undertake. He could not acknowledge any mistake in reference to *Porospongia*.

December 18, 1872.

Benjamin Winstone, Esq., 53 Russell Square, W.C.; William Aubone Potter, Esq., of Cramlington House, Northumberland; Thomas Sopwith, Jun., Esq., the Holmes, Nightingale Lane, Clapham Common; Philip Charles Hardwick, Esq., 21 Cavendish Square, W.; Frederick George Hilton Price, Esq., 25 Clarendon Gardens, Maida Vale, N.W.; Charles Lapworth, Esq., Abbotsford Road, Galashiels, N.B.; Henry Brogden, Esq., of the Llynn, Tondu, and Ogmore Coal and Iron Works, Glamorganshire; John Wonnacott, Esq., 15 Haddington Road, Stoke Devonport; and Alfred Cecil Crutwell, Esq., Cardiff, were elected Fellows of the Society.

The following communications were read:—

1. Further Notes *on the* Punfield Section. By C. J. A. Meyer, Esq., F.G.S.

In a paper read before the Society in March 1872*, I stated my conviction that the so-called "Punfield Formation"† of the Isle of

* Quart. Journ. Geol. Soc. vol. xxviii. p. 252. † Judd, *ibid.* vol. xxvii. p. 207.

Purbeck was superior in position to the "Lobster-clay" of Atherfield—or (to state the matter more clearly) that the Punfield beds, from the "marine band" upwards, were Lower Greensand instead of Wealden, representing, however, only so much of the Lower Greensand of the Isle of Wight as would be included between the "Lobster-clay" and the Gault.

The assertion was a bold one, and should, I am well aware, have been supported at the time by fuller evidence. It was not, however, put forward thoughtlessly; and I have now to offer such further evidence as may tend towards a settlement of the points in question.

To test the truth or error of my impressions with respect to the relation of the Isle-of-Wight *Wealden* and *Neocomian* strata to those of Punfield, I revisited the coast-sections at Redcliff and Atherfield, and spent several days in studying the corresponding strata in Compton Bay. I sought carefully in either formation for such change in its passage westward as might indicate the relation of either to the marine, or semi-marine, Punfield beds of the Isle of Purbeck.

The Wealden beds showed no such change. But for slight variations in thickness and disposition, these Upper Wealden shales of the Isle of Wight are almost perfectly alike at Compton Bay, at Sandown, and at Atherfield. The section of the Wealden strata of Compton Bay has been already given with great accuracy in the Memoirs of the Geological Survey*; and on this point it is therefore needless to enter into detail.

Unlike the Wealden, the condition of the Greensand strata of Compton Bay is much altered in appearance from what may be seen at Atherfield. Their upper and middle portions are extensively and distinctly laminated†, and put on already very much the appearance of the more laminated portions of the Punfield strata. They contain more lignite and apparently fewer fossils in comparison than the corresponding strata at Atherfield. The "Crackers rock" is scarcely recognizable at Compton, its position being merely indicated by semi-indurated nodules of shell-rock. The "Lobster-clay," however, is, fairly represented; and although the *Perna*-bed and underlying grit, or passage-bed, are nowhere visible at their outcrop, on account of the fallen masses of the low undercliff, their presence at this point has been long since satisfactorily determined. Masses of the grit-bed, with its characteristic Neocomian fossils, may be picked up abundantly along the shore.

So far, then, the evidence obtainable from the Wealden and Neocomian strata in their most westerly exposure in the Isle of Wight tended mainly to strengthen my previous belief as to the real position of the Punfield beds of Punfield. The next step to be taken was to reexamine the Punfield Section, and to obtain fuller evidence, if possible, as to the condition of the strata beneath the so-called "marine band."

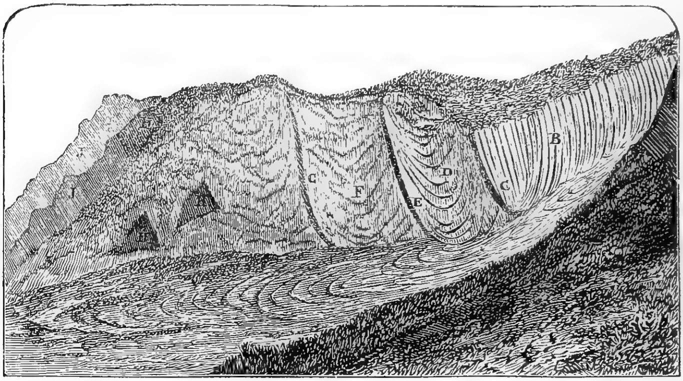
With this intent I returned to Punfield towards the end of October,

* Mem. Geol. Surv. (Geol. I. of Wight), chap. iii. p. 9, fig. 7. † Ibid, p. 9.

and found the sections more clearly exposed than on my previous visit. Owing probably to the unusual rainfall of the autumn, and the consequent washing-down or slipping of the softer sands and clays, the harder bands towards the base of the section were unusually well defined. By standing at a little distance, so as to obtain a clear general view of the cliff-section, I now saw that I had hitherto much underrated the thickness of the lower clays. It was now evident that the strata between the so-called "marine band" and the "variegated beds" of the Wealden must amount to a thickness of nearly one hundred feet, or more than twice the thickness I had previously ventured to assign to them.

The sketch, fig. 1 (which gives a fair representation of the lower

Fig. 1.—*Sketch of lower part of Cliff-section at Punfield Cove.*



B. Laminated sand and clay, with lignite. C. Marine band, with *Vicarya.* D. Lobster-clay. E. Sandstone and shell-bed, with Lower Greensand fossils. F. Atherfield-clay. G. Grit-bed. H. Shales of Upper Wealden. J. Variegated beds of Middle Wealden.

part of the Punfield Section), indicates very clearly the positions of the various groups of strata to which I have now to refer.

In this section the strata J represent the so-called variegated beds of the Middle Wealden.

The strata H, the greater portion of which is covered by vegetation, consist, where visible, of finely laminated sands and sandy clays. These last resemble very much in appearance the "paper-shales" of the Wealden of Compton Bay and Atherfield, but, so far as I had time to observe them, contain only a few minute fish-bones.

The next stratum exposed, marked G on section (fig. 1), is the *grit-bed* described in my previous paper as probably representing the passage-bed between the Wealden and Neocomian. It consists of a layer of hard sandstone or ironstone-grit, passing downwards, within the thickness of a few inches, into limestone, laminated claystone, and *paper-shale.* The gritstone contains fish-bones and traces of *Cypris.* The limestone is here and there crowded with *Cypris* in the

lines of cleavage. I obtained here also, from a fallen mass of clay-stone a few specimens of *Cyrena**.

The strata between the hard bands G and E of section fig. 1, were again too closely covered by vegetation to afford an insight into their real condition. They appeared to be mainly argillaceous, but of this I am far from certain.

The hard band E of section fig. 1 stands out in the cliff at the distance of from 15 to 20 feet beneath the so-called "marine band." It consists of a double layer of semi-indurated or concretionary sand-stone, more or less ferruginous in colour, and passes upwards, within two or three feet, first into sandy clay, and then into stiff, greyish clay, D, which I described in my former paper as representing the "Lobster-clay" of Atherfield.

On picking into this clay-bed D with a small pointed hammer, I presently obtained traces of marine fossils, *Arca* and *Exogyra*. Continuing the search downwards into the sandy clay just above the hard band E, I found these marine fossils to be extremely abundant. In about half an hour I had before me, to my great delight, the casts and impressions of a number of undoubted Lower Greensand fossils. Although few of these retained the shell, the species were, with two or three exceptions, easily recognizable. The following list sufficiently indicates their character:—

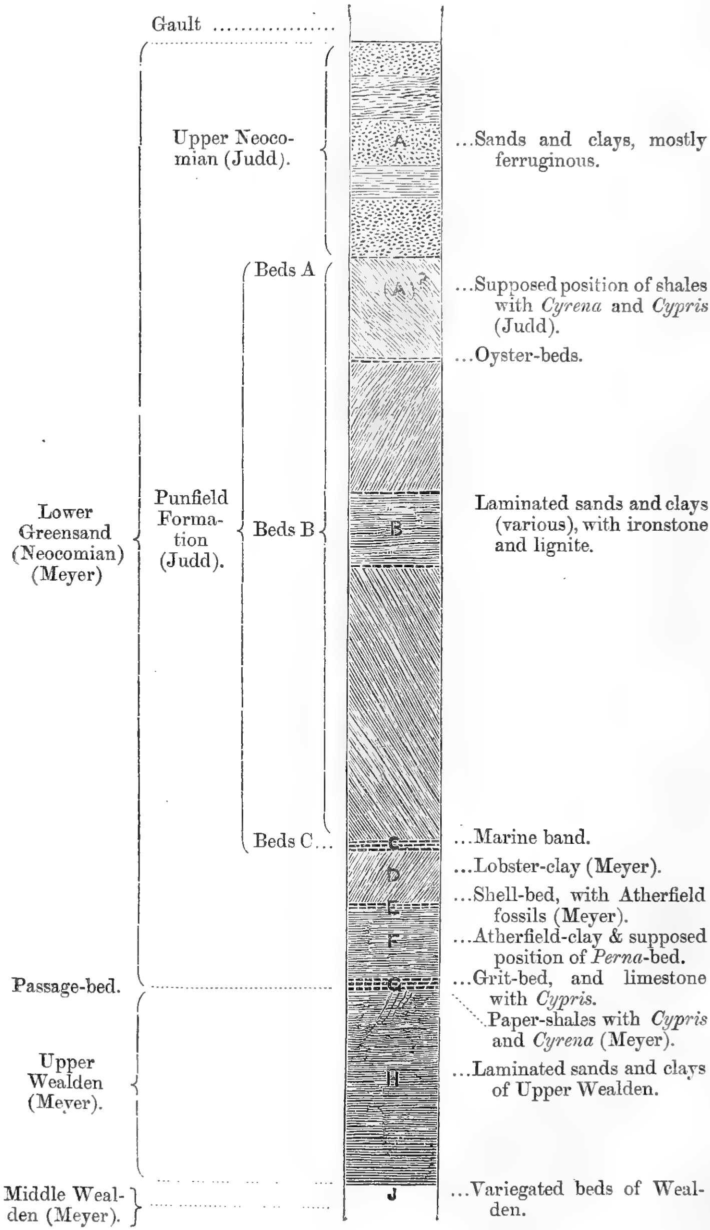
Fossils from beneath the "Lobster-clay" at Punfield.

Terebratula sella, *Sow.*
Anomia lævigata, *Sow.*
Exogyra Boussingaultii, *D'Orb.*
—— Tombeckiana, *D'Orb.*
—— sinuata, *Sow.*, var., =E. aquila, *D'Orb.*
Ostrea Leymerii, *D'Orb.*
Pecten Robinaldinus, *D'Orb.*
——, sp.
Neithia (Pecten) neocomiensis, *D'Orb.*
Arca Raulini, *D'Orb.*
—— Austeni, *D'Orb.*
—— cornueliana, *D'Orb.*
Astarte (?)
Cardita neocomiensis, *D'Orb.*
Cardium subhillanum, *D'Orb.*
Cardium, sp.
Corbula, sp.
Cyprina, sp.
Cytherea parva, *Sow.*
Lucina, sp.
Modiola simplex, *Leym.*
Panopæa neocomiensis, *D'Orb.*
——, sp. (=P. plicata, var., of Atherfield).
—— Prevosti, *D'Orb.*
Solecurtus Warburtoni, *Forbes.*
Thetis lævigata, *D'Orb.*
Trigonia (Atherfield species).
—— (Atherfield species).
Venus, sp.
Three or more species indeterminable.

Here, then, was at last the clearest evidence which could well be required as to the correctness of the views expressed on this subject in my former paper. These fossils are the common species of the Atherfield clay. They come in at Punfield, as elsewhere, beneath the "Lobster-clay" and above the "shales with *Cypris*" of the Upper Wealden; and although the "*Perna*-bed" has not as yet been found at Punfield, there is now I think but little doubt of its ultimate dis-

* The species here mentioned as occurring in and beneath the grit-stone are *Cypridea tuberculata*, Sow., *C. valdensis*, Sow., and *Cyrena media*, Sow., which are, by the way, the common species of the Upper Wealden. Is it not possible that Fitton's specimens of *Cypris* and *Cyrena* were also obtained from this horizon?

Fig. 2.—*Diagram showing the succession and relative thickness of the various groups of strata at Punfield, from the Gault to the Middle Wealden, and their respective relation to the Lower Greensand.* (Scale 1 in.=50 ft.)



covery. Its position should be somewhere between the hard bands G and E of my section.

The letters C and B on diagram fig. 1 indicate respectively the "marine band" and the "laminated clays and sands with lignite" of the Punfield strata. Of these I have nothing new to say.

The diagram fig. 2 illustrates in full my present reading of the Punfield section. It shows at a glance the comparative thickness and succession of the various groups of strata between the Gault and the Middle Wealden, and their (probable) respective relation to the Wealden and Neocomian (Lower Greensand) of the Isle of Wight.

The points involved in this question, "as to the relation of the Punfield strata to the Wealden and Neocomian," are at the present moment necessarily of considerable interest; but, while feeling that I am but doing my duty as a student of Secondary geology, in once more bringing this subject before the Geological Society, I must disclaim any desire that the question should remain to be decided on my evidence alone.

Discussion.

Mr. Judd congratulated the author on the interesting nature of his discoveries, which in his opinion bore out most completely his own views and those of others who had worked before him in the same field. He cited Dr. Fitton, Mr. Godwin-Austen, and Sir Charles Lyell as regarding the beds as unquestionably Wealden, though with some marine bands accidentally intermingled. Prof. Ed. Forbes, Prof. Phillips, and the Geological Survey had also regarded these beds as Wealden, notwithstanding the temptation there existed from stratigraphical reasons to place them in the Lower Greensand. These authors had supported their views of the Wealden nature of these beds by collections of freshwater fossils, some of which were figured, and are still preserved in public collections. He had himself regarded the Punfield series as Neocomian, though still closely connected with the Wealden, and, in fact, forming a transitional series of beds between the two, though absolutely belonging to neither, and therefore worthy of a distinctive name, in this respect resembling the Purbeck and Rhætic. He accepted the author's view, as carrying the boundary of these transitional beds to a lower level than that previously assigned to them. In correlating the Punfield beds with those of the Isle of Wight, he disputed the value of the evidence of the lobster-beds, which, as had been pointed out by Edward Forbes, must of necessity have varied in character at points any considerable distance apart.

Mr. Seeley had regarded the Punfield beds from the same point of view as Mr. Meyer, and had all along felt objections to the opinion of Mr. Judd. This had been partly the result of his observations of the section, partly the result of the palæontological evidence. By following the beds westward he had arrived nearer the source of the materials of which they were composed, and had noted more particularly a certain grit-bed which he thought could be recognized through the whole series, and therefore afforded a sort

of basis for argument. The beds thinned out to the west and thickened to the east. He was prepared to accept the two lobster-beds, which in the section were one over the other, as merely showing the persistence of the same bed, which, though continuous, had changed its position during the interval.

Prof. T. Rupert Jones considered that certain beds in the Wealden were susceptible of correlation over very wide areas by means of certain brecciated beds. He pointed out that near Pulborough and at other places the Wealden terminated in paper shales, the same as those which Mr. Meyer had placed at the top of the series at Punfield. Above these he thought no purely freshwater beds were to be found. He considered that the whole, including the Wealden, were included in the Neocomian.

Mr. Etheridge thought the difference between the various writers on this subject to be mainly one of terms. The same fossils as those found at Punfield had been found in abundance in Spain.

Mr. Meyer maintained, in opposition to Mr. Judd, that the Punfield beds were not merely Upper Wealden. He had found a certain form of *Ostrea* over large areas always on the same horizon; and this had occurred at Punfield at precisely the level at which, in accordance with his views, it ought to have been present. Above the marine bands he had sought in vain for freshwater fossils.

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2. *On the* Coprolites *of the* Upper Greensand Formation, *and on* Flints. By W. Johnson Sollas, Esq., Associate of the Royal School of Mines, London; Scholar of St. John's College, Cambridge.

(Communicated by the Rev. T. G. Bonney, M.A., F.G.S.)

[Abstract.]

Part I.

The first part of this paper was principally occupied in an endeavour to explain the perfect fossilization of sponges and other soft-bodied animals. It was shown that the hypothesis which considered that sponges had become silicified by an attraction of their spicules for silica was altogether untenable. Mr. Hawkins Johnson's supposititious reaction, according to which the carbon of animal matter is directly replaced by silicon, was shown to be inconsistent with the known facts of chemistry. The author's explanation was not intended to be final. The first fact pointed out was the very remarkable way in which the silica or calcic phosphate of the fossils under consideration followed the former extension of organic matter. This was explained for silica by the fact that, when silicic acid is added to such animal matters as albumen or gelatin, it forms with them a definite chemical compound; and it was assumed that in process of time this highly complex organic substance would decompose, its organic constituents would be evolved, and its silica would remain behind. In such a way flints might be produced, and dialysis would lend its aid. The same explanation was applied to account for the connexion

between calcic phosphate and animal matter in the case of the "Coprolites."

The Blackdown silicified shells were next explained; and it was reasoned that the state of their silica offered arguments tending to prove a passage of silica from the colloidal to the crystalline state.

Part II.

Coprolites, as has already been stated, are the result of the phosphatization of organic matter. They may be classed according as their origin is known or obscure. The progress of discovery transfers the obscure forms into the class of known forms; but there will always remain a certain number which cannot be thus transferred—those, for instance, which have been produced from soft-bodied animals in the last stage of decomposition, all traces of their structure having been obliterated. The fossil remains of Reptiles, Fish, and Crustacea, the casts of Mollusks, and the perfectly preserved Ventriculites are instances of coprolites about whose origin there is no uncertainty; but besides these easily recognizable kinds there remain a vast majority of forms which, from their want of any striking characters, have always been obscure. In this paper the author proposes to transfer these in great part among the fossil sponges.

General Character of the Coprolites.

In the Greensand, most of the coprolites are of a black or deep brown colour, while in the Gault they are greyish-white on the surface, but brownish-black internally. By etching the greensand coprolites with acid they change, however, to the same greyish-white colour as the specimens from the gault; and masses of agglomerated coprolites are met with in the Greensand which, when broken open, reveal nodules of their original light colour.

The surfaces of most of the coprolites are variously marked with (i.) fold-like depressions, (ii.) osculiform pits, (iii.) puncta, and (iv.) contraction cracks.

(i.) The depressions occur as fold-like markings, which sometimes run longitudinally with remarkable constancy in size and direction for nearly the whole length of the fossil; besides this they may take any other direction. These grooves are marked by very minute wrinkles, which give the whole depression the appearance of one of the creases stretching from button to button in the leathern back of an easy chair. The better-marked of these grooves scarcely appear to be due to contraction consequent on fossilization.

(ii.) The circular or oval osculiform pits vary in size, frequently being $\frac{1}{20}$ of an inch in diameter. Their margins are often depressed into a concave border, which is striated by regularly radiating "groovelets." These commence at the sides of the osculiform pit, pass across the concave border, and either stop there or pass to a greater or less distance on the surrounding surface. In some specimens these little striations are more restricted and better-defined than in others, and in some they are altogether absent.

The osculiform pits are grouped sometimes at the end of one of the wrinkled depressions above described; sometimes they are collected in sieve-like patches, or two or three may be noticed at the bottom of a wider-mouthed pit, while occasionally they are terminal, and frequently dispersed. It may be noticed that in the same specimen these pits occur of very various sizes, and that the striated grooves of their margins are never arranged in any multiple of four—an argument, if arguments are needed, against the alcyonioid origin of these forms.

(iii.) The puncta are minute pore-like markings, which appear in the greensand specimens as mere specks of a different nature from the rest of the fossil; but in the gault coprolites they are the distinctly open terminations of fine canals.

(iv.) Contraction-cracks are evident on the surfaces of many specimens, generally filled in with lighter-coloured material. In the coprolites from the Gault the oscula, puncta, canals, cracks, and other cavities are either empty or filled with loose clay; in those from the Greensand all these cavities are infiltrated with phosphatized chalk-marl, containing green grains and sometimes diffused glauconite. Since these infiltrated coprolites of the Greensand are derived from those of the Gault, which are not infiltrated, this filling-in must have taken place after the greensand fossils were washed out of their matrix.

Smooth surfaces of attachment are to be seen on some specimens; and in rare cases the shell on which they grew remains adherent to them.

General Appearances under the Microscope.—Thin sections examined under the microscope vary from colourless to yellowish-brown when transparent, but sometimes they are almost opaque from included earthy matter. Granular patches of a deep red colour are sometimes scattered throughout the lighter-coloured portions. Spicules occur in many sections, presenting some of the most characteristic forms of sponge-spicules, as for example, hexaradiate, triradiate, hamate, sinuate, and connecting forms. These spicules are frequently grouped together in a manner which would seem to indicate that they cannot have been washed in from the sea-bed during fossilization. Globular bodies $\frac{1}{400}''$ in diameter are numerous; they seem to be gemmules. *Polycystina* and *Xanthidia* occur in some sections. With polarized light the sections appear distinctly cryptocrystalline, presenting an appearance very nearly resembling that of chalk flints when examined in the same way. A very curious phenomenon may be alluded to here. A number of small circles may be seen in some sections, each of which is marked by a black cross, the arms of which radiate from the centre to the circumference. On turning the analyzer the cross revolves and, when he analyzer has been turned round 90°, is replaced by a complementarily illuminated cross. The explanation of these appearances seems to be as follows: small *Globigerina*-shells and other similar spaces occur in the coprolite, into which the crystalline apatite which was diffused throughout the fossil has penetrated and crystallized inwards

from their walls to their centres, thus forming a radiating mass of crystals; it is well known that crystals arranged in this manner will produce the phenomena described.

Behaviour with Hydrochloric Acid.—Hydrochloric acid dissolves the coprolites, some undergoing solution more readily than others, owing to their containing a larger quantity of calcic carbonate. While dissolving they emit a smell almost precisely resembling that of petroleum. The hydrocarbons which produce this odour must exist previously as gases, or combined with the calcic phosphate of the coprolite. I believe that they are present in the latter condition. The insoluble residue left on solution very frequently contains sponge-spicules and siliceous organisms; these may be separated in the same way as Foraminifera are obtained from a piece of chalk.

Enumeration of Genera *.

Genus 1. Rhabdospongia. *Sponge* more or less rod-like, 1″ to 2″ long, $\frac{1}{3}''$ to $\frac{1}{2}''$ diameter. Frequently attached at one end. *Cloaca* none, solid throughout. *Spicules* filiform, acerate, sinuous. *Species*: R. communis.

Genus 2. Bonneyia. *Sponge* cylindrical to clavate, size variable. *Cloaca*: longitudinal axis always occupied by a cloacal cavity from $\frac{1}{3}$ to $\frac{2}{3}$ of the whole diameter of the fossil. *Spicules* few. *Species*: B. bacilliformis, B. cylindrica, B. Jessoni, B. scrobiculata, B. verrongiformis.

Genus 3. Acanthophora. *Sponge* massive, lobose. *Spicules* acerate, fusiform, spiculated porrecto-ternate and recurvo-ternate, triradiate, hexaradiate. *Species*: A. Hartogii.

Genus 4. Polycantha. *Sponge* ovate. *Cloaca* present. *Spicules* acerate, defensive, triradiate, quadriradiate, hexaradiate. *Species*: P. Etheridgii.

Genus 5. Retia. *Sponge* cylindrical or hemicylindrical, marked on surface with a symmetrical fibre-like reticulation. *Spicules* few or absent. *Species*: R. simplex, R. costata.

Genus 6. Hylospongia. *Sponge* large and massive. *Cloaca* always present. *Surface* covered by a bark-like exterior, beneath which it is smoothly and longitudinally striated. *Species*: H. patera, H. calyx, H. Brunii.

Discussion.

Mr. Charlesworth complained that the author had not fully stated Dr. Bowerbank's views, which were founded on the fact that flint, wherever found, whether in fissures, the interior of organisms, or elsewhere, always presented under the microscope a reticulated structure. He had himself combated the view that flint was in all cases silicified sponge, and had demonstrated that certainly, in some cases, flint had been formed without the intervention of sponges; for in the case of the teeth in a lower jaw of a *Mosasaurus* found in the Chalk, he had found the pulp-cavities completely filled with

* Mr. Etheridge, after an examination of specimens, says that he entirely approves of these generic groupings.

black flint. At the same time the bone and dentine had remained unsilicified. Even in this flint, however, Dr. Bowerbank thought he had recognized spongy texture, and accounted for the presence of sponge in so singular a position in what seemed to be by no means a satisfactory manner. Mr. Charlesworth maintained that siliceous matter did not always follow organic fibre, and that in the case of most Ventriculites the flint never embraced the whole of the organism. In the chalk of the southern parts of England, the roots and upper portion of Ventriculites were hardly ever to his knowledge completely silicified. In Yorkshire, on the contrary, the whole body of the sponge was silicified, and flint was but rarely found of other forms. He called attention to the fact that when a shell, such as that of an Echinoderm, was completely filled and enveloped by flint, it remained in the state of carbonate of lime; when only filled but not enveloped, a portion of the shell had been replaced by silica.

Prof. T. Rupert Jones regretted that observations in this country were principally confined to the flints of our southern Chalk. He had himself never seen such silicified shells of Echinoderms as those described by Mr. Charlesworth. He considered that in many cases the flint was, in fact, pseudomorphous silica after amorphous carbonate of lime, and that there was a gradual change from carbonate of lime into silica taking place; so that the theory of the author was not in all cases applicable.

Rev. O. Fisher did not understand how dialysis could have segregated a mineral from a solution surrounding an immersed body on all sides. He thought the coprolites had not been derived from the Gault, but that they came out of a chloritic marl which was not truly Upper Greensand.

Mr. Carruthers thought that the speculations in the first part of the paper, though interesting, formed only a portion of a very large subject; and he would be glad to see the considerations extended to the fossilization by silica of other bodies than sponges. He thought in most instances the silicification was the result of what took place long after the organisms had been imbedded in the rock.

Mr. Gwyn Jeffreys stated that in deep-sea explorations he had found both siliceous and calcareous sponges in the same area. He had taken them both alive and dead, and in no case was there silicification. In the case of Foraminifera, however, he had found the interior filled with silica, evidently by infiltration.

Mr. Hawkins Johnson stated that he had not confined his remarks in the paper cited by the author to the substitution of silicon for carbon, but had instanced that as only one of the steps towards silicification.

Mr. Evans mentioned the late M. Meillet, of Poitiers, as having some years since pointed out the cause of the whitening of flint by age.

Mr. Woodward pointed out that the condition of most silicified Ventriculites seems to afford evidence that the process had gone on at a period long subsequent to their being imbedded in the Chalk.

Prof. Williamson commented on the difficulties of the case, and said he believed that in most fossils more than one process had con-

duced to the result. He agreed with Mr. Charlesworth as to the character of the Yorkshire fossil sponges, in which the silica had most completely replaced the keratose fibres. By the action of acid it was possible to obtain their skeletons as perfect as those of living species. There had been no mere infiltration in the case, but a real chemical union between the silica and the keratose fibres. At Flamborough Head, close by silicified sponges, he had found others in which the organic matter had been entirely replaced by oxide of iron instead of silica; and these, on being treated with acid, were dissolved. In the case of the Foraminifera, three distinct operations had taken place—one an infiltration, another the conversion of animal matter into flint, and the third that of calcareous matter into flint also.

Mr. Sollas in reply pointed out that he had not stated that flint was formed by the silicification of sponge-tissue, but by that of animal matter. He did not think that any mere mineral change could account for the forms of flints. He had only dealt with a limited portion of the question of the origin of flint and coprolites. Of the organic origin of the latter there could be no doubt. He thought that the non-silicified condition of recent dead sponges might be due to a defective supply of silica in the sea-water. He had not put so much stress on dialysis as had been supposed, but relied mainly on the deposition of flint by means of organic matter. From the presence of *siliceous* spicules of peculiar forms in the coprolites, he could not accept them as of Alcyonarian origin.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

January 8, 1873.

Joseph Channing Pearce, Esq., M.B., The Manor House, Brixton Rise, S.W.; H. George Fordham, Esq., University Hall, Gordon Square, W.C.; and Richard Dickson Poppleton, Esq., Lesney Villa, Erith, Kent, were elected Fellows of the Society.

The following communication was read:—

The Secondary Rocks *of* Scotland. By John W. Judd, Esq., F.G.S. First Paper. *With a* Note *on some* Brachiopoda, by Thomas Davidson, Esq., F.R.S., F.G.S.

[Plates VII. & VIII.]

Contents.

General Introduction.

The Highlands of Scotland have long been recognized as an unrivalled field of study for the physical geologist; but to the stratigraphical geologist and the palæontologist, who seek for evidence to aid them in reconstructing the geographical features and determining the biological characteristics of successive geological periods, they have, till of late years, been regarded as comparatively barren of interest. An exception to this general statement must be made, however, in favour of the Old Red Sandstone of the district, which has yielded such admirable results to the studies of Murchison, Sedgwick, Malcolmson, Hugh Miller, Agassiz, and others.

Charles Peach's discovery in 1854 of Silurian fossils in Sutherland has already borne the most important fruit, and, in the hands of Murchison, Ramsay, Geikie, Harkness, and Jamieson, has afforded the necessary clue for determining the age of the great *Primary* masses of the Highlands.

Similarly the discovery by the Duke of Argyll of Miocene vegetation in beds intercalated with the basalts of Mull has been the starting-point in elucidating the history of the *Tertiary* period in the Highlands. Professor Geikie has already laid before this Society the first of a series of papers in which he proposes to treat this interesting subject.

The *Secondary* strata of the same area were, at so early a period as 1826, made the object of an admirable general survey by the late Sir Roderick Murchison; but the progress of geological science

since that date appears to create a demand, and at the same time to afford the necessary means, for a fuller and more minute investigation of the subject.

The isolated rock-masses of Secondary age which occur in th Highlands and Western Isles of Scotland, must ever be objects of the highest interest to geologists. They are evidently the vestiges of formations once widely spread, and have escaped the extensive denudation which has to such an enormous extent destroyed the contemporary and even older deposits of the district. Preserved to our study by accidents of the most striking character, they are now found in very unexpected situations, lying in the midst of the Older Palæozoic and often highly metamorphic rocks. On the eastern coast, as we shall see in the sequel, faults of enormous magnitude have let down these patches of Mesozoic strata among the older formations; while on the western coast the fragments of Secondary age which had escaped the enormous denudations of the Middle Cretaceous and Older Tertiary eras, were subsequently sealed up and preserved under thousands of feet of volcanic rocks, by the wearing away of which, at a period geologically recent, they have been at a few points exposed to our observation.

These fragments of Mesozoic strata, the true nature of which was first recognized by Macculloch, Buckland, and Lyell, were in 1826–7 made the subject of careful study by the late Sir Roderick Murchison. Rightly perceiving that the nearest analogues of these rocks would be found, not in the contemporary purely marine deposits of the south of England, but among the estuarine strata of Oolitic age in Yorkshire, that distinguished geologist prudently prefaced his work by a careful study of the latter under the able guidance of William Smith and John Phillips.

If the analogies of the Scotch with the Yorkshire strata were allowed too great weight, and, owing to the difficulties of the investigation at a time when our science (and especially the palæontological department of it) was still in its infancy, incorrect conclusions as to the exact age of many of these deposits were arrived at, every investigator of the subject will nevertheless gladly acknowledge the great value of this pioneer work of the master hand whose loss we still mourn. On every page of his memoir we recognize those powers of acute observation, of clear description, and of happy generalization which characterized the geologist who afterwards from the chaos of Transition and Grauwacke evolved the order of Siluria.

Since the date of those early researches Geology has made the most prodigious strides; and in no department have its advances been more rapid, and the results obtained more important, than in that which relates to the study of the Jurassic rocks. The direction and tendency of modern discovery and research have been such as to invest the outlying and fragmentary Jurassic deposits of Scotland with a new and deeper interest, and to call for their examination from a fresh point of view.

By the comparison of the persevering and minute researches of

indefatigable observers at many points, we are now able to perceive that the districts at present constituting England, Northern France, and Western Germany were included during the Jurassic and Neocomian periods within a single marine province, the very uniform succession of life in which has been clearly traced. Thus a palæontological scale has been constructed which, with due precautions, may be safely used for the determination of the age of any isolated rock-masses which were deposited within the limits of this old marine province. Further, the relations of the different strata and the conditions under which they were deposited at various points have been so far investigated that some progress has been made in determining the boundaries of the several gulfs, channels, and islands of that great sea and archipelago which constituted this life-province. This, in turn, has led to the recognition and study of the minor palæontological features which characterized the several subdivisions of that sea, and, in a much less degree (owing to the paucity of the evidence), of the several land-areas which bounded them.

Lastly, a considerable amount of knowledge has been gained of the succession of the movements of upheaval and subsidence by which the boundaries of the sea and land within this area were at different periods modified.

To the interesting patches of Jurassic strata in the Highlands of Scotland, then, we resort, and, in spite of the fragmentary character of the evidence in many instances, seek in them for the solution of many problems of the highest geological interest, among which we may especially instance the following:—

(1) The determination of the northern limits of the old life-province to which we have referred, and the question whether the Scotch deposits were formed within it.

(2) The special palæontological features of the province or subdivision of a province to which these strata belong.

(3) The conditions under which the various beds constituting the Mesozoic series in Scotland were deposited.

(4) The influence of climate in affecting the modes of deposition, and consequent character, of the rocks, and also in modifying the palæontological features of the area.

(5) The position and extent, with the nature and productions, of the lands bounding this portion of the old Mesozoic sea.

(6) The character and succession of the subterranean movements which affected the area during the Jurassic and subsequent epochs.

On each of these problems the study of the Highland strata throws important light; and to some of them it affords satisfactory and complete solutions. That in a case like the present, where the rocks preserved and exposed are of such a fragmentary character, some unfortunate gaps in the evidence will have to be lamented, is of course no more than might be anticipated; yet I hope to be able to show in the sequel that, by a careful examination, with the aid of the palæontological key, of every trace of these rocks left to us, the cases of total hiatus in the evidence are reduced to a remarkably small number, and that we are, in fact, able to sketch with

great completeness the history of the Jurassic system in Scotland, and to furnish many details with regard to that of the Triassic and Cretaceous.

I. *General Characters of the Jurassic Strata of Scotland.*

When we compare the Jurassic series as displayed in Scotland with that of the typical district of the south of England, we find many differences of a very striking and highly suggestive character. In the latter area the whole series, from the base of the Lower Lias to near the top of the Upper Oolite, is represented by strata which, while exhibiting evidence of having been deposited under very various conditions, determined by depth of water, distance from the shore, and nature of sediment, are yet all of undoubted *marine* origin. It is only at the commencement of this great period, in the Rhætic, and towards its close, in the Portland and Purbeck strata, that we find evidence of the *estuarine* conditions which afterwards prevailed during the deposition of the Anglo-French Wealden far into the Neocomian period.

As we proceed northwards into the Midland district of England, the Jurassic system begins to exhibit several intercalated series of beds with estuarine characters; but these, though of great interest in themselves, are nevertheless, as compared with the great mass of marine strata with which they are associated, subordinate in character and insignificant in extent.

In Yorkshire, however, there is evidence that, during the whole period of the Lower Oolite, estuarine conditions prevailed over a considerable area, and a series of strata was deposited consisting of sandstones, shales, ironstones, and thin seams of coal, which attains to a thickness of about a thousand feet; the marine beds associated with these are of a subordinate and local character. The other Jurassic strata in Yorkshire are of purely marine origin.

In Scotland, as I shall show in the present memoir, this gradual change of character in the Jurassic system as we go northwards, is carried still further. I shall have to describe the occurrence there, from the base of the Lower Lias up to and including the Upper Oolite, of a number of series of beds exhibiting estuarine characters. These alternate with marine strata, which, however, are often of very subordinate character and limited thickness. As is usually the case with strata deposited under these conditions, the succession of beds is found to undergo great changes within comparatively short distances; and thus the sections, at points not very remote from one another, often exhibit very remarkable contrasts. In some places the strata of estuarine origin are found to greatly exceed in thickness those of marine character, while in others the former are subordinate to the latter.

This gradual change in character of the Jurassic series, as we pass from south to north, finds a singular parallel in the Carboniferous system. There, as is so well known, the marked distinction between the marine strata of the Mountain-limestone at the base,

and the estuarine Coal-measures above, which characterizes the south of England, is gradually lost in going northwards,—beds of estuarine character gradually descending lower in the series in Yorkshire, as first shown by Professor Phillips, still lower in Northumberland, as described by Mr. G. Tate; while in Scotland, as has been illustrated by Professor Geikie and other writers, the whole Carboniferous series from top to bottom consists of estuarine strata with subordinate marine beds intercalated.

The estuarine strata of Jurassic age in Scotland exhibit two different types of petrological character, which, though occasionally passing into one another by insensible gradations, are usually very distinct and easily recognizable. These we may distinguish as the argillaceous and arenaceous types. The fossils of these estuarine strata usually afford us comparatively little aid in determining the age of the several series: our knowledge of the succession of forms among the freshwater mollusca is far too limited for us to obtain much aid from this source; and the few marine bands intercalated contain, as a rule, only specimens evidently dwarfed from unfavourable conditions, and scarcely ever belonging to highly characteristic forms like the Cephalopods and Echinoderms. The groups of marine strata, however, which alternate with the estuarine yield very fine and satisfactory faunas, by the study of which we are able to fix with great precision the limits of age of the latter.

The *arenaceous* type of the estuarine strata is characterized by beds of sandstone and grit, occasionally passing into conglomerates, and becoming in places somewhat calcareous. These alternate in some cases with subordinate beds of shale, and occasionally contain thin and imperfect seams of coal. The sandstone strata, which often attain to a great thickness, usually exhibit evidence of having been deposited under comparatively shallow-water conditions: false-bedding abounds; surfaces with ripple-marks, worm-tracks, and other indications of the proximity of the shore frequently occur; and the rock is usually crowded with fragments of carbonaceous matter. Large masses of wood, sometimes preserved as jet, and at other times presenting only hollow casts, abound in these sandstones; and occasionally vertical plant-markings, like those of the Lower Oolite in England, are also found. Not unfrequently we observe a rock made up of alternations of laminæ of sand and carbonaceous matter, so exactly resembling the strata seen in sections of old sand dunes, as strongly to suggest a similarity of origin. In all these sandstone strata molluscan remains are usually extremely rare; but occasionally bands of obscure shells, almost always in the form of casts, are found; these sometimes belong to marine, and at other times to freshwater genera.

The general resemblance of all these strata of the arenaceous type to those of the Lower Oolites of the Yorkshire coast is very striking; and it was not unnatural that, at the early date at which they were first studied by Sir Roderick Murchison, this should be accepted as evidence of identity of age. Hence the whole of these

strata have been hitherto regarded as contemporaneous with the Lower Oolites of Yorkshire. I shall, however, be able to show, from the manner in which the various series of estuarine beds, both on the east and west coasts of Scotland, alternate with marine strata, of which we are able to fix the age by the most conclusive palæontological evidence, that the former belong to various periods, from the Lower Lias up to the Upper Oolite.

The *argillaceous* type of estuarine strata, though usually forming series of much less thickness than those of the arenaceous type, presents many features of great interest. It is characterized by finely laminated clays, usually of green, blue, grey, and black colours, sometimes more or less sandy, and passing into fire-clay, and containing impure argillaceous ironstone in bands and nodules. These laminated clays contain also thin bands of limestone, sometimes crowded with shells of *Cyrena*, *Unio*, and other freshwater bivalves, sometimes with *Paludina* and other freshwater univalves, and at others made up of dwarfed *Ostreæ* and other marine shells, crowded together in masses, and forming beds exactly resembling the well-known "Cinder-beds" of the Purbeck. As in that formation, too, we frequently find thin seams of fibrous carbonate of lime, so well known to the workmen under the name of "beef-" and "bacon-beds." In these clays beds crowded with the valves of *Cyprides* and *Estheriæ* also occur, with veritable bone-bands, made up of scales and teeth of fish and bones of reptiles. Not unfrequently these clays are crowded with plant-remains; and interstratified with them occur beds of lignite or coal, sometimes several feet in thickness, some of which have been worked with success.

No one can examine these strata of the argillaceous type without being at once struck with their resemblance to those of the Purbeck formation, and also to those of similar character which occur at the top of the Wealden in the Isle of Wight and elsewhere, which I have described in detail under the name of the Punfield Formation. As the general similarity in character of the strata of the arenaceous type to the Lower Oolites of Yorkshire has led to their being indiscriminately referred to that age, so the peculiar characters of the strata of the argillaceous type have at various times led to the announcement of the discovery of Wealden, Purbeck, and Rhætic strata in Scotland. These strata, however, will be shown to belong to various portions of the Jurassic period; beds of precisely similar character occur in the Lower Oolites of the Midland district of England.

Nowhere is the fallacy of inferring the contemporaneity of deposits from the similarity of mineral composition so strikingly illustrated as in the Jurassic strata of Scotland. While from such resemblances in general characters, when due allowance has been made for metamorphism subsequent to deposition, we may usually safely conclude the conditions under which the two series were respectively formed to have been similar, yet to base any argument on them as to age can scarcely fail, as in the present instance, to lead to the most serious errors.

The marine strata associated with the various groups of estuarine beds in the Scotch Jurassic system also exhibit many very interesting characters. As compared with their equivalents in England, they usually show indications of having been of more shallow-water origin, and accumulated under conditions of a much more local character. While on the one hand there is a general absence of the thick masses of clays, formed of fine sediment and crowded with pelagic forms of life, like large portions of the Lias, and the Oxford and Kimmeridge clays, we find in many parts of the series great accumulations of conglomerate made up of the local rocks. At the same time there are not wanting proofs that, during certain portions of the Jurassic period, marine conditions prevailed over a very considerable area; and it is in these that the strata are found to assume the comparatively deeper-water and more normal characters.

The remarkable feature of the frequent recurrence of estuarine strata, though *characteristic* of the Scottish Jurassic series, is not *peculiar* to it. In the southern province of Sweden (Scania) we find a precisely similar set of phenomena to those which we have been noticing as so strikingly displayed in Scotland.

In Sweden the Secondary strata are exposed under the same disadvantageous conditions as in Scotland. Almost everywhere the surface of the country is concealed by great masses of drift of various kinds, above which a few hard ridges of Mesozoic rocks rise in isolated patches. Some of these patches are composed of Chalk and Upper Greensand; others of Jurassic strata presenting very peculiar characters. The exact geological relations of these singular fragments of Secondary strata have not apparently been fully determined, but, like the similar beds of Scotland, they are developed in the immediate vicinity of great masses of Silurian and granitic rocks. The Jurassic strata of Sweden consist of alternations of sandstones, shales, grits, quartzose conglomerates, impure lignites, and workable seams of coal: in some places these beds yield a beautiful flora; in others they contain bands with marine shells. These strata have been studied by Wahlenberg, Nilsson, Hisinger, Murchison, Braun, and others: and by some authors, as Brongniart and Mantell, they have been regarded (as were the estuarine Jurassic beds of Scotland) as representing the Wealden.

The two most important patches of these strata, those of Högonäs and Hör, have lately been made the object of careful and exact study by M. Hébert, who has shown that the marine strata at the base of the former contain a fauna which enables us to assign them to the base of the Lower Lias, while the evidence with regard to the latter, though less decisive, is such as to lead us to consider them to be of nearly the same age *.

Thus we see that there are reasons for believing that over a vast area, comprising the northern limits of the Anglo-Parisian basin, a

* "Recherches sur l'âge des grès combustibles d'Helsingbord et d'Högonäs (Suède méridionale), par M. Hébert," Annales des Sciences géologiques, tom. i. p. 117; Bull. de la Soc. Géol. de France, 2e série, tom. xxvi. (1870) p. 366.

similar set of conditions prevailed at the Jurassic epoch, marked by the deposition of strata of an estuarine character throughout the whole period. I need here only point out how remarkably this fact confirms the conclusion drawn from other premises by Mr. Godwin-Austen *, of the existence of an extended land-area during the Jurassic period, in the north-European area—reserving the discussion of the other interesting questions suggested by it for the third part of this memoir.

II. *The Cretaceous Strata of Scotland.*

There are not wanting grounds for inferring, *à priori*, that rocks of the Cretaceous system once extended over large portions of Scotland; and this inference has received the strongest support from the discovery, by numerous observers, of chalk-flints in great abundance, with transported masses of Greensand, in the drifts of the north-east of the country, as well as from the fact, recorded by the Duke of Argyll † and Professor Geikie ‡, of the existence of beds of chalk-flints, sometimes of great thickness, under the basalts of the Western Isles. But hitherto no rocks of Cretaceous age have been detected *in situ* in the British Islands to the north of Yorkshire and Antrim. During my study of the Jurassic rocks of Scotland, however, I have had the good fortune to discover very interesting Cretaceous deposits of considerable extent, though often much obscured by overlying volcanic rocks. These occur in the west of Scotland, on the mainland, and also in several of the islands, and, as might be anticipated, present characters similar to those of the equivalent strata of the north of Ireland, of which they are evidently the northern prolongation; at some points, however, they exhibit other features of much novelty and interest, for which we must seek a parallel in the Tourtia and other continental deposits. These Cretaceous strata are also of the greatest interest and importance as affording the most complete confirmation of the conclusions of the Duke of Argyll and Professor Geikie as to the Tertiary age of the Hebridean volcanic rocks.

III. *The Triassic Strata of Scotland.*

Another formation, the existence of which in Scotland has been considered by some geologists almost as problematical as that of the Cretaceous, is the Trias. The keen discussions, however, concerning the age of the now celebrated reptiliferous sandstone of Elgin appeared to many geologists to be terminated by the palæontological researches of Professor Huxley, referring to which Sir Roderick Murchison, in the last edition of 'Siluria,' wrote as follows:—"To such fossil evidence as this the field-geologist must bow; and instead, therefore, of any longer connecting these reptiliferous sandstones of Elgin and Ross with the Old Red Sandstone beneath them, I willingly adopt the view established by such fossil evidence, and consider that these overlying sandstones and limestones are of Upper

* Quart. Journ. Geol. Soc. vol. xii. (1856), pl. 1.
† Quart. Journ. Geol. Soc. vol. vii. (1851), p. 94.
‡ Proc. Roy. Soc. Edin. vol. vi. (1867), p. 72 &c.

Triassic age, and must once have formed the natural base of those Liassic and Oolitic deposits of the north-east of Scotland which I described forty years ago" *.

Most strikingly has the anticipation contained in the above passage been verified by my researches among the newer strata of Sutherland during the past year. I have been able to detect there the formation so long the subject of controversy, and to show that its relations to overlying rocks are exhibited in a section free from those sources of difficulty and doubt which have so long baffled geologists in Elginshire. In Sutherland the rocks in question are seen to be covered conformably by a great series of strata which, as will be seen from their large and distinctive faunas, represent various members of the Middle and Lower Lias. Thus, as in so many similar instances, the apparent discrepancy between the palæontological and stratigraphical evidence is dissipated by further inquiry, and the proof of the Triassic age of the beds in question is rendered complete.

The object of the present memoir is to give the results of a careful study of the small but highly interesting patches of Secondary rocks which occur in Scotland, with a view to show how far the history of the Mesozoic periods within that area can be reconstructed from them. It is proposed to divide the subject into three parts, which will be successively communicated to this Society, the first being embodied in the present paper. The three divisions of the memoir are as follows:—

I. The Secondary Strata of the Eastern Coast of Scotland.

II. The Secondary Strata of the Western Coast and Islands of Scotland.

III. A general Comparison of the Scottish Mesozoic Strata with their equivalents in England and on the Continent, and an examination of the Theoretical Questions suggested by a study of their physical characters and relations, and of the peculiarities of their faunas.

Part I.—Strata of the Eastern Coast.

I. *History of Previous Opinion.*

The coal-beds of Brora were certainly known as early as the year 1529, as is proved by an ancient Sutherland charter, which was brought under my notice by the Rev. J. M. Joass. This charter is quoted in the 'Origines Parochiales Scotiæ' (vol. ii. pt. ii. p. 727).

The earliest account of the working of the coal is contained in Sir Robert Gordon's quaint old work 'Genealogy of the Earls of Sutherland,' written in 1630.

John Williams, the author of the 'Natural History of the Mineral Kingdom,' was lessee of the Inverbrora Colliery from 1764 to 1769. He does not, however, in his work, which was published in 1810, record any of his observations and experiences in Sutherland, though he notices the peculiar characters and gives some details

* Siluria, 4th edition (1867), p. 267.

concerning the position of the remarkable rock of Stotfield in Elginshire, which contains galena (*op. cit.* vol. i. pp. 303, 401).

In 1811 Sir Humphry Davy made an examination of the rocks of Sutherland, especially noticing the strata which are found on the south-eastern coast of the county, and wrote a short account of them. These observations were never published; but the MS. and the series of specimens collected by the author to illustrate his descriptions are preserved in the Duke of Sutherland's Museum at Dunrobin.

Captain John Henderson's 'General View of the Agriculture of the County of Sutherland,' published in 1812, preserves a copy of one of the sections made during the trials for coal at the Water of Brora (Fascally).

In 1812 John Farey, sen., the well-known author of the 'Mineral Report on Derbyshire,' and the friend and correspondent of William Smith, made a professional examination of the Sutherland coal-field. His Report, which is in MS., and is dated 29th April, 1813, is a most valuable essay; it is accompanied by an admirable series of sections and maps; and in the execution of the whole of these the author has vindicated his claim to be regarded as one of the foremost among the pioneers of geological science. Farey, like Townsend and Richardson, clearly foresaw the important fruit which the discoveries of Smith were destined to produce, and, like them, sought everywhere to apply those principles which his friend taught, and to collect new facts to aid him in his generalizations. Fully recognizing the importance of the study of fossils as characterizing particular rocks, he made collections from several of the Secondary beds in Sutherland, and transmitted them to Mr. Sowerby; some of these fossils were afterwards figured in the 'Mineral Conchology.' Farey was the first to detect the fact that the coal-bearing strata of Sutherland do not belong to the true Carboniferous system, but are of Secondary age: he also traced clearly the position of the several coal-seams, and the character and effects of some of the principal dislocations to which they have been subjected. To the geologist at the present time Farey's Report is of especial service, preserving, as it does, accurate records of old pits and sections now no longer open; and I am happy to acknowledge the great services which I have myself received from it.

In 1819 Mr. Robert Bald laid before the Wernerian Natural-History Society of Edinburgh an account of the Clackmannanshire coal-field, in which he furnishes some details of the peculiarities of the strata seen at Brora. His paper was published in 1821, in the memoirs of the above-named Society (vol. iii. p. 138).

About this time Mr. George Anderson, of Inverness, an indefatigable local observer, laid before the Philosophical Society of that town a paper on the Sutherland coal-field, which appears never to have been published; his experience, however, would seem to have been subsequently placed at the service of Sir Roderick Murchison, who warmly acknowledges the assistance received from him.

In 1824 Dr. Buckland and Mr. (now Sir Charles) Lyell visited Sutherland, and recognized the fact that the coal-bearing beds were

of Oolitic, and not of Carboniferous age. No account of their researches, however, appears to have been printed.

In 1826 Mr. (afterwards Sir Roderick) Murchison visited the county, and made that careful survey of the Jurassic strata in Sutherland, Ross, and Cromarty, to which reference has already been made (Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2, p. 293).

In the following year (1827) Murchison returned to the Highlands in company with Professor Sedgwick. On this occasion, the Secondary rocks were reexamined, and the first detailed study made of the Triassic rocks of Elginshire (Trans. Geol. Soc. 2nd ser. vol. ii. pt. 3, p. 353, and vol. iii. pt. 1, p. 125).

At this period Dr. Knight, of Aberdeen, had already detected the fact of the existence of chalk-flints over a large area in the county of Aberdeen; and in a paper published in the Edinburgh Philosophical Magazine in 1831, Mr. Christie called attention to the occurrence of chalk-flints at Boyndie Bay, Banffshire.

In 1832 appeared the first edition of the admirable 'Guide to the Highlands' by George and Peter Anderson, of Inverness, in which some valuable geological observations are recorded.

The same year Dr. Gordon, in a letter to Sir Roderick Murchison, read before the Geological Society, gave the first notice of the existence of a patch of Secondary rock in Morayshire at Linksfield, or Cutley Hill, near Elgin (Proc. Geol. Soc. vol. i. p. 394).

In the year 1835 the Highland and Agricultural Society published a prize essay on the 'Geology of Morayshire,' the work of Mr. John Martin. This work contains many valuable details connected with our subject. In 1838 Dr. Malcolmson showed that the beds at Linksfield presented remarkable resemblances in mineral characters to the English Wealden and Purbeck, to which period he suggested that they belonged. In the same year appeared his admirable essay on the Old Red Sandstone of Morayshire, in which he treated of the beds now placed both on palæontological and stratigraphical grounds in the Trias.

Mr. R. Hay Cunningham's 'Geognosy of Sutherlandshire,' another of the prize essays of the Highland and Agricultural Society, appeared in 1839. In this work, however, which contains such an admirable account of the Palæozoic rocks of the county, scarcely any fresh facts are added with regard to the Secondary rocks.

In 1842 appeared Mr. Duff's 'Sketch of the Geology of Moray,' in which many valuable details are given concerning the rocks of that county (which are now placed in the Trias), and also with regard to the fragments of Jurassic rocks scattered over the county, which are now proved to be transported masses included in the Boulder-clay.

Mr. Alexander Robertson, of Inverugie, laid before this Society, in the years 1843 and 1846, admirable essays on the section below the coal of Brora, showing that there were intercalated in the series bands of freshwater shells, and insisting that, from the resemblance of these strata to the Wealden, they ought to be classed with that formation (Proc. Geol. Soc. vol. iv. p. 173, and Quart. Journ. Geol.

Soc. vol. iii. p. 113). The same author, in the 3rd edition of Anderson's 'Guide to the Highlands,' gave an admirable sketch of the geology of the county of Elgin. It was through the agency of the same indefatigable geologist that the fishes of Linksfield, and the first discovered specimen of *Stagonolepis*, were submitted to Prof. Agassiz, by whom they were described in the 'Poissons Fossiles.'

The year 1852 forms an important era in the history of discovery in connexion with the Secondary rocks of the east of Scotland; for then was first brought under the notice of geologists the existence of the interesting reptile *Telerpeton Elginense*, which was described by Dr. Mantell, while its position in the rocks of Elginshire was clearly pointed out by Captain Brickenden. The latter gentleman had in the previous year contributed some interesting notes to this Society on the position of the mass of Secondary rock at Linksfield (see Quart. Journ. Geol. Soc. vol. vii. p. 289, and vol. viii. pp. 97 and 100).

Hugh Miller, in his early work 'The Old Red Sandstone,' published in 1841, makes reference to the supposed Liassic strata of Eathie; and during the numerous examinations which he made of his native county and adjoining districts, he collected many very interesting observations on the Secondary rocks, which are recorded in several of his deservedly popular works, especially in 'The Fossiliferous Deposits of Scotland' (1854), 'Rambles of a Geologist' (1858), 'The Cruise of the Betsy,' (1858) and the 'Sketch-Book of Popular Geology' (1859). Many of these observations will be referred to in the following pages. Hugh Miller's most important contribution to the Secondary Geology of Scotland, however, is the account which he gives, in the eleventh and twelfth chapters of the 'Testimony of the Rocks,' of the beautiful flora, now shown to be of Upper Oolite age, of Sutherland and Ross.

The doubt which had been awakened by the discovery of *Telerpeton* as to the Old-Red-Sandstone age of the sandstones of the north of Elginshire was greatly intensified by Professor Huxley's announcement that the *Stagonolepis* of Agassiz was not a fish, as had hitherto been supposed, but a reptile of high organization, and with Crocodilian affinities. When, by the indefatigable labours of Dr. Gordon, a third species of reptile, the *Hyperodapedon Gordoni*, was brought to light, and its close affinities with well-known Triassic genera demonstrated by Professor Huxley, even the stoutest advocates of the Old-Red-Sandstone theory, including Sir Roderick Murchison, began to waver.

When the British Association met at Aberdeen in 1859, this great open question of geology was warmly discussed, many geologists taking the opportunity of examining the district; the Triassic age of the Reptiliferous sandstone was strongly maintained by Sir Charles Lyell, Mr. C. Moore, and the Rev. W. Symonds.

In the same year Dr. Gordon published his admirable *résumé* of the known facts 'On the Geology of the Lower or Northern part of the Province of Moray,' while Sir Roderick Murchison gave a discussion of the whole question in a paper read before this Society. The history of the changes of opinion on the subject can also be traced

in the several editions of Sir Charles Lyell's 'Manual of Geology,' and of Sir Roderick Murchison's 'Siluria.'

In 1863 the Old Red Sandstone theory appeared to receive some support from the discovery of footprints in the sandstones of the Tarbet Ness promontory by the Rev. Geo. Campbell and the Rev. J. M. Joass; and in the following year Professor Harkness, while admitting that the sections of Sir Roderick Murchison across Elginshire could not be maintained, and that the country was certainly traversed by great faults, yet argued that, nevertheless, the stratigraphical evidence was in favour of our regarding the Reptiliferous sandstone as belonging to the Old Red.

Professor Huxley's new and detailed account of *Telerpeton* in 1867 was followed in 1869 by the description of *Hyperodapedon Gordoni*; and in this latter memoir it was shown that the *same genus* occurs in the Trias of Warwickshire, Devonshire, and India. This discovery was admitted by Sir Roderick Murchison and most other geologists to be conclusive as to the Triassic age of the beds.

While the attention of geologists was concentrated on the Reptiliferous sandstones, but little fresh light was thrown on the other Secondary deposits of the east coast of Scotland. Mr. C. Moore, in 1859, published his reasons for considering the strata at Linksfield of Rhætic age; which view was supported by Professor Rupert Jones on a study of some of the fossils. The Rev. W. Symonds stated in 1860 that a collection of Eathie and Shandwick fossils, on being submitted to some able Cotteswold palæontologists, were pronounced by them to be of Upper Oolite and not of Liassic age. Hugh Miller had already suggested that part of these strata were probably Oolitic, while Professor Phillips in 1870 stated that his examination of Lieut. Patterson's collection led him to infer that they belonged to the Oxfordian*. Dr. Gordon, in 1863, published some notes on the physical relations of the secondary strata in Ross and Sutherland; and in his most valuable work the 'Scenery of Scotland,' Prof. Geikie in 1865 added some important observations on the same subject.

In making a general reexamination of the Secondary deposits in the east of Scotland, some facilities have fortunately been afforded to me which were not within the reach of previous observers. Thus the new railway which passes along the east coast of Sutherland has yielded several new and interesting sections in the various cuttings; while the coal-strata, which had remained undisturbed for 44 years, were during the time of my visit again opened up to observation at several points.

By the establishment at Dunrobin of a Museum illustrative of the

* Professor Phillips has recently furnished me with an extract from his notebook, which shows that the inspection of Lieut. Patterson's collection in 1866 convinced him that the beds at Eathie and Shandwick belonged to two different horizons, and that the peculiar long Belemnites were found only at the former place. Unfortunately, some specimens with a wrong locality affixed to them, afterwards came into the Professor's possession, and led to the less precise statements in his account of these Belemnites in the memoir.

natural history, geology, and archæology of the county from which he derives his title, and of which he is almost the sole proprietor, His Grace the Duke of Sutherland has conferred a great benefit on science; and the same nobleman has placed myself under deep personal obligations by allowing me the freest access to the various documents and plans which could in any way aid me in carrying on my studies. The kind solicitude in my behalf of His Grace's Factor, Joseph Peacock, of Rhives, demands my warmest acknowledgments. To very many local collectors and observers I am indebted for the opportunity of studying their specimens, and for the communication of valuable facts. Among these I especially desire to render my warmest thanks to Mr. Grant, of Lossiemouth, the Rev. J. Morrison, of Urquhart, Mr. Martin, of Elgin, Mr. Edward, of Banff, Professor Nicol, of Aberdeen, Mr. Hugh Miller, junior, Miss C. Allardyce, of Cromarty, Mr. Fowler, of Golspie, and Mr. M'Corquodale, of Dunrobin.

But to two local geologists, whose names are well known to this Society, I am laid under still deeper obligations. To the Rev. J. M. Joass, of Golspie, and the Rev. Dr. Gordon, of Birnie, near Elgin, I am indebted for that constant assistance and ever-ready advice which they are so well qualified to give with regard to their respective districts, and which is so indispensable to and difficult of attainment by an investigator in a district which is new to him. The kind interest which they have taken in my labours, and their constant solicitude in seeking to bring useful materials to aid me in the difficult task which I had undertaken, lay me under a debt of gratitude which, though I can never discharge, I yet gladly take the present opportunity of acknowledging.

The orthography of all local names in the present memoir has been kindly determined for me by my friend Mr. Joass; but in doing this he has, at my suggestion, consulted the convenience of geologists visiting the country, rather than the strict requirements of Gaelic scholarship.

In studying the series of fossils from the east of Scotland, many of which are new to science, I have to acknowledge the valuable assistance afforded to me by Mr. Carruthers, Dr. Lycett, Prof. P. M. Duncan, Sir Philip Egerton, Prof. T. Rupert Jones, and Mr. Davidson. The last-mentioned palæontologist has kindly added a note to this paper on some species of Brachiopoda of especial interest; many other new forms will find a place in monographs, now in course of preparation, on the groups to which they belong; the remainder will be described, in connexion with new species from the West Coast of Scotland, in a supplement to this memoir. In these palæontological studies, the assistance of Mr. Etheridge's great experience, always most liberally rendered to me, has been invaluable.

II. *Physical Relations of the Secondary Rocks on the East Coast of Scotland.*

The Secondary rocks which are known to occur *in situ* on the

east coast of Scotland, consist almost exclusively of more or less isolated patches, often of small extent, on the shores of the Moray Firth. It is possible that the Boulder-clays and other drifts, which attain to so great a thickness in the north-east of Scotland, may conceal other similar patches; these we can only expect to be revealed to our observation through some favourable combination of circumstances, in deep natural or artificial sections.

The masses of Mesozoic strata which are seen at various points round the Moray Firth, are found lying indiscriminately against the different Palæozoic rocks—namely, the several members of the Old Red Sandstone, the metamorphic rocks of the Lower Silurian, and the great bosses of granite. The Secondary strata are usually greatly bent and faulted, and often, especially near their junction with the Palæozoic rocks, very violently contorted. The strata are shown by their palæontological characters to be of various ages, from the Trias to the Upper Oolite, and, as will appear from the present memoir, enable us to reconstruct nearly the whole of the Jurassic series as developed in this northern district.

None of the beds exhibit evidence of having been beaches lying upon the old Palæozoic rocks with which they are now in contact, and made up of their fragments. Common as this phenomenon is, as we shall see hereafter, on the west coast of Scotland, we find nothing resembling it on the east coast, where the conglomerates and grits are never made up of the detritus of the primary rocks lying nearest to them; but on the contrary the various beds of the series exhibit indications of the most various modes of origin—deep-sea marine, shallow-water marine, littoral, brackish-water, freshwater, and terrestrial.

It is evident on an examination of these patches of Secondary strata that they form the last remaining vestiges of extensive formations which once covered considerable areas, but have been almost wholly removed by the enormous denudation to which the district in which they are developed has been subjected; it is equally plain that the present position of the patches among the older rocks must be ascribed to accidental causes, which have operated since their original deposition. In almost every instance we can trace the *proximate* causes of the preservation of the patches, either in the presence of rocks of especial hardness and capability of resisting denuding influences, like the cherty rock of Stotfield, the indurated sandstones of Braamberry Hill, the hard grits of Kintradwell and the breccias of Helmsdale—or in the position and protective influence of surrounding masses of Palæozoic rocks, as at Eathie and Shandwick. The more *remote* causes which have contributed to the preservation of the several patches I shall presently demonstrate. That, even as late as the glacial period, the Secondary rocks covered much more extensive areas than at present appears to be proved by the great abundance of their fragments in the Boulder-clay of the east of Scotland.

The areas covered by the Secondary rocks which have been as yet discovered are, as already intimated, very small; and as they are

almost always deeply covered with masses of Boulder-clay, gravels, glacier-moraines, raised beaches, and sand dunes, they are seldom exposed to our observation, except in reefs on the shore or in the deep ravines cut by mountain-torrents.

The patches of Secondary strata at present known on the east coast of Scotland are as follows, the enumeration proceeding from north to south (see Map, Plate VII.):—

CAITHNESS.—I. A small patch forming reefs on the shore a little north of Green Table Point. *Age.* Upper Oolite.

SUTHERLAND.—II. Several masses of strata almost continuous, between Green Table Point and Helmsdale. *Age.* Upper Oolite.

III. A continuous band of strata between Helmsdale and Allt Chollie (Colyburn). From $\frac{1}{4}$–$\frac{1}{2}$ mile wide. *Age.* Upper Oolite.

IV. A tract extending from Kintradwell to near Golspie. This attains a breadth of more than 2 miles at Brora, and is by far the most important development of the Secondary rocks in the east of Scotland. *Age.* From the Trias to the Upper Oolite (inclusive).

ROSS.—V. A patch of clays seen at low water on the shore at Port-an-Righ, near the mouth of the Guillam Burn, and a little south of Shandwick Bay. It extends for about three-quarters of a mile between two projecting spurs of Old Red Sandstone. *Age.* Upper part of Middle Oolite.

VI. A similar but smaller patch, only half-a-mile south of the last, at a place called Cadh'-an-Righ. *Age.* Base of Middle Oolite, and top of Lower Oolite.

CROMARTYSHIRE.—VII. Beds similarly exposed on the shore at Eathie Bay over a length of about three quarters of a mile. *Age.* Upper Oolite.

ELGINSHIRE.—VIII. The ridge of low sandstone hills between Burghead and Stotfield Head, and part of the ridge three miles to the southward, and on the south side of Loch Spynie. The boundaries of these patches are altogether obscured by drift. *Age.* Trias and Lower Oolite.

Besides these points, at which the strata in question are undoubtedly *in situ*, there are a number of places scattered through the counties of the north-east of Scotland, especially Elginshire, Banffshire, and Aberdeenshire, where very numerous fragments of the Secondary rocks have been detected enclosed in the Boulder-clays, which are there so extensively developed; and from these boulders very considerable and interesting series of Secondary fossils have been obtained. In some cases the transported masses are of enormous size, resembling the similar blocks found in the Midland districts of England, and referred to by Prof. Morris* and Prof. Ramsay†, and which will be described in detail in a forthcoming

* Quart. Journ. Geol. Soc. vol. ix. (1853) p. 317.

† *Ibid.* vol. xxvii. (1871) p. 252.

memoir of the Geological Survey. In other instances, although the individual blocks are not large, there are evidently local accumulations of fragments from the same bed, perhaps the deposits of single icebergs. The most notable example of the former kind is that of Linksfield, which has been several times brought under the notice of this Society; while striking instances of the latter kind occur at Inverugie, Lhanbryd, and Urquhart; these and similar cases have led to reports of the existence of Secondary strata *in situ*, afterwards proved to be erroneous*.

With regard to the general relations of the patches of Secondary strata in the east of Scotland to the great masses of Palæozoic age which constitute the Highlands, the conclusions to which Sir Roderick Murchison appears to have been led by his first examination of the strata on the east coast of Sutherland were as follows:—That the Jurassic beds were deposited in a basin formed of the Old Red Sandstone rocks, and that subsequently a great upheaval of granite *in a solid condition* caused the vast amount of disturbance and contortion seen in some parts of the strata of the former series†. Later observations appear to have convinced Sir Roderick Murchison that some portions of what he originally regarded as a granitic rock, were really stratified and metamorphic‡; but he has not in his later writings sought to harmonize this fact with the theory of the relations of the rocks which he originally put forward. In the section across Sutherland, published in the 'First Sketch of a Geological Map of Scotland' in 1861§, the Old Red Sandstone and the Jurassic series are represented, probably through inadvertence, as following the Silurian in nearly conformable sequence.

Mr. Hay Cunningham, in his examination of the county of Sutherland in 1839, clearly perceived that all the southern part of the crystalline rocks, against which the Jurassic strata of that country lie, are really stratified and metamorphic, and not granitic. In his map he indicates, with tolerable correctness, the range of these metamorphic rocks, though he does not carry them sufficiently far to the southward‖; and he further identifies them with the great series of gneissic rocks which covers so large a part of Sutherland. Rejecting, on these grounds, Murchison's explanation of the peculiar phenomena of the district by the upheaval of granite in a solid condition, Mr. Cunningham himself put forward a theory to account for them, which, however, is likely to find but little acceptance among geologists at the present day. He argues that the Jurassic strata might have been originally deposited in their present condition of high inclination, and that the "brecciated" appearance

* See Duff, 'Geology of Moray,' 1842; Prestwich, Quart. Journ. Geol. Soc. vol. ii. p. 545; Hugh Miller, 'Rambles of a Geologist,' &c. 1858; &c. &c.

† Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2. pp. 295, 307, 354, &c., pl. 31.

‡ *Ibid.* pt. 3. p. 355.

§ This Map is republished in Geikie's 'Scenery of Scotland,' 1865.

‖ See also the Map published by the Rev. J. M. Joass, to illustrate the distribution of the auriferous deposits in Sutherland, Quart. Journ. Geol. Soc. vol. xxv. (1869), pl. xiii.

of some of them (that extraordinary phenomenon which has justly excited the wonder and severely taxed the ingenuity of Murchison and other geologists who have examined and attempted to account for it) might be due to the breaking-up and redeposition of some of the beds*.

I shall now proceed to describe the facts which I have been able to observe concerning the position of the Jurassic strata, and their relations to the Palæozoic rocks, and then indicate the conclusions to which they point as to the circumstances of deposition and of the subsequent disturbances of these strata. By this means I hope to be able to demonstrate what were the *remote* causes which led to the preservation of the interesting masses of Mesozoic strata to be described in the present memoir.

It will be convenient, in order to make the subject as clear as possible, to describe a line of section passing across the centre of the most important Jurassic area, where the rocks attain their greatest development and present the most satisfactory exposures. Such a line of section we have, as pointed out by Sir Roderick Murchison, passing through Clyne and Brora, and crossing a breadth of upwards of two miles of Secondary strata. When the main facts with regard to this most important section have been established, it will only be necessary to refer, in more general terms, to the various sections to the north and south of it respectively which serve to illustrate the relations of the Secondary to the Primary strata.

§ 1. *Description of the Section through Beinn-Smeorail, Clyne Kirk, and Brora*, N.W. to S.E. (fig. 1).

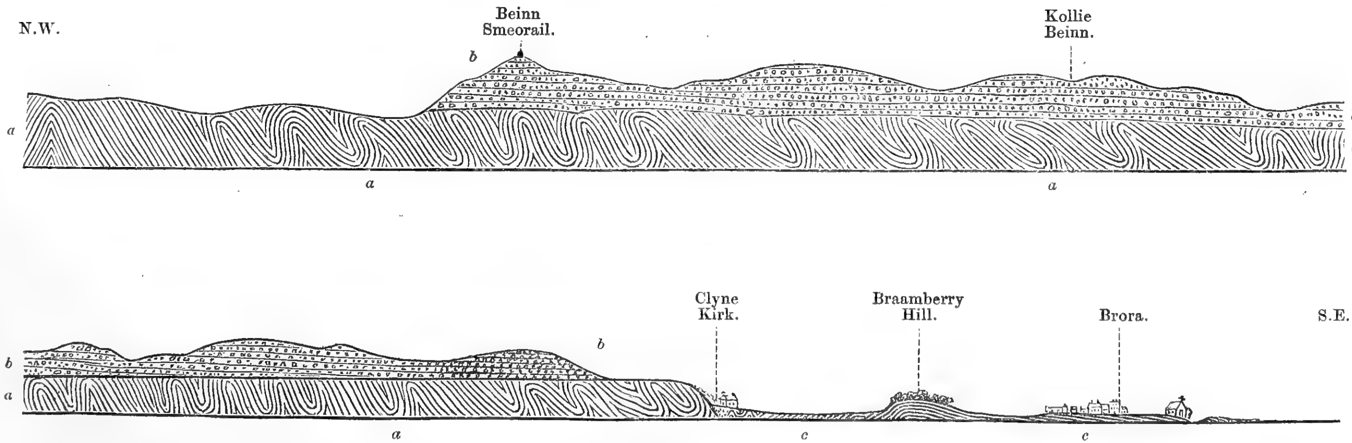
The great series of metamorphic rocks which covers all the central parts of Sutherland, have now, through the discovery of fossils by Mr. C. Peach, and the study of the physical relations of the beds by Sir Roderick Murchison and Professors Ramsay, Geikie, and Harkness, been referred to the age of the Lower Silurian†. These rocks, which have been very happily termed by Murchison "altered flagstones," present the most varied characters, passing from flaggy quartzites or altered sandstones, in which crystalline minerals just begin to appear along the planes of stratification, up to the most highly granitic gneiss, and perhaps into true granites. The prevailing dip of these strata is towards the south-east; and they are usually inclined at very high angles, often greatly contorted, and sometimes traversed by numerous veins of granite, quartz, felspar, &c. As a rule they do not form striking elevations, and give rise to but tame and monotonous scenery‡.

* "On the Geognosy of Sutherlandshire," by R. J. H. Cunningham (1839), p. 37, published in vol. xiii. of the 'Transactions of the Highland and Agricultural Society of Scotland.'

† Quart. Journ. Geol. Soc. vol. xiv. (1858) p. 501; vol. xv. (1859), p. 353; vol. xvi. (1860), p. 215; vol. xvii. (1861), p. 171; vol. xvii. (1861), p. 256; vol. xviii. (1862), p. 331.

‡ These strata have been more particularly described by the Rev. J. M. Joass, Quart. Journ. Geol. Soc. vol. xxv. (1869), p. 314.

Fig. 1.—*Typical Section, illustrating the relations of the Secondary Deposits to the Palæozoic Rocks of Sutherland.*



a. Lower Silurian gneissose rocks, greatly contorted. *b*. Lower Old Red Sandstones and Conglomerates made up of fragments of *a*, and resting on the denuded edges of its strata. *c*. Middle and Upper Oolites, exhibiting evidence of great disturbance at their junction with *a*.

Lying upon the upturned and denuded edges of these Silurian rocks there is, on the south-east coast of Sutherland, a series of outlying masses, forming a belt about five miles wide, and consisting of the Lower division of the Old Red Sandstone system. This is constituted by nearly horizontal beds of the well-known and highly remarkable rock of the Old Red Conglomerate (which is made up of fragments of all sizes, waterworn and angular, of the subjacent Silurian rocks) alternating with, and frequently graduating into, more or less flaggy beds of Red Sandstone composed of what Sir Roderick Murchison aptly calls "*granitic sand.*" Nothing can be more striking than the proofs of unconformity between the Silurian and Old Red Sandstone rocks: the former have evidently been not only contorted and metamorphosed, but also upheaved and denuded before the deposition of the latter; and the older strata have, moreover, furnished the materials of which the younger are composed.

The relation of these two series of rocks may be well seen on both sides of Loch Brora, where the tops of the fantastically shaped mountains, which culminate in Beinn-Smeorail and Beinn-Hourn, are formed of the Old Red Conglomerate and Sandstone, while their flanks, wherever mountain-torrents have cut through the old lateral glacier-moraines which cover them, are seen to be formed of the highly contorted Silurian rocks*. On the south-eastern side of the band of the Old Red strata the Silurian distinctly appears; but the rock, being of a somewhat peculiar character, was originally mistaken for granite. It is almost entirely made up of quartz and felspar, and is generally in a more or less altered condition, being divided by numerous joints into small angular fragments the surfaces of which are decomposed and stained with oxide of iron†. When, however, a sufficiently large surface of fracture can be obtained, the laminar arrangement of the crystalline materials of the rock is perfectly manifest. Mr. Cunningham states that a rock of precisely similar character forms part of the series of strata, now recognized as Silurian, at Beinn-Laoghal and some other points in the interior of Sutherland; and fragments of the rock certainly occur as pebbles in the Old Red Conglomerate.

In the admirable section exposed in the ravine near Clyne Kirk‡ the Silurian rocks, which rise to the height of about 500 feet (at which elevation their greatly contorted strata are seen to be capped by the nearly horizontal Old Red Sandstone beds), terminate abruptly;

* Near Kilcallumkil (Gordon Bush) a great mass of Old Red Sandstone has tumbled from the mountain above nearly to the level of the Loch; and in it a quarry has been opened. Nowhere can the geologist find better illustrations of glacial phenomena than on the shores of the exquisitely beautiful Loch Brora. Of especial interest are the numerous terminal moraines, which mark the gradual retrocession of the glacier of Strath Brora, and one of which still dams up the present lake. Professor Geikie has referred to this most interesting locality in his admirable book on the Scenery of Scotland, p. 203–4.

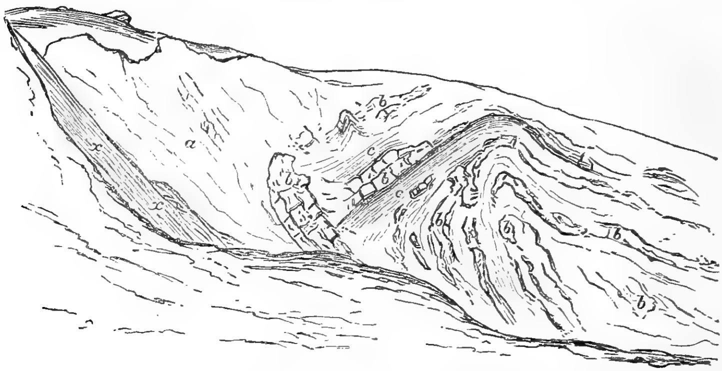
† This rock affords an admirable material for macadamizing roads, as it falls when quarried into suitable angular fragments, without needing the labour of the "stone-breaker."

‡ See Cunningham, 'Geognosy of Sutherlandshire,' pl. vii.

and lying against them, but rising to a much smaller height, on account of their comparative softness, the Jurassic beds appear. The accompanying sketch (fig. 2) shows the appearance of the junction

Fig. 2.—*Section in the Ravine above Clyne Kirk, showing the junction of the Secondary and Palæozoic rocks.*

N.W. S.E.



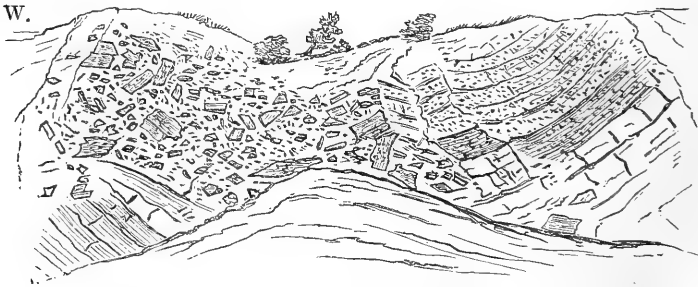
x. Metamorphic (Silurian) rocks. *a, b, c*. Jurassic Rocks.
a. Sand and sandstone so broken up that the stratification is undistinguishable.
b. Beds of coarse white and yellow sandstone, } greatly contorted.
c. Finely laminated, highly carbonaceous sand and clay, }

of the Palæozoic and Mesozoic strata on the north-east side of this gorge. The Silurian rocks (*x*) form the precipice, over which the stream falls in a fine cascade. The Jurassic rocks here consist of sandstones, argillaceous sands with much carbonaceous matter, and

Fig. 3.—*Sketch of the Oolitic beds seen in Allt-Chollie (Colyburn), illustrating the manner in which they are crushed and broken near their junction with the Palæozoic rocks.*

← { Lower Silurian Gneiss &c. seen a little higher up the ravine. E.

W.



some thin beds of clay: these strata do not yield sufficiently perfect fossils to enable us to fix their exact place in the geological series; but, judging from their mineral characters, I am inclined to refer them to the Upper Oolite. At (*a*) the strata are very obscure, being

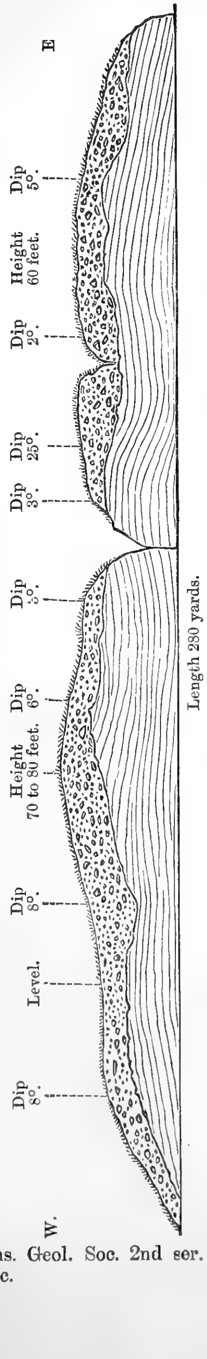


Fig. 4.—*Section of the Middle Oolite beds (Ornatus-Clays), as seen in the Bluff on the north side of the River Brora, illustrating the rolling undulations into which the Jurassic Strata are thrown at some distance from their junction with the Primary Rocks.*

covered with slipped masses and vegetation; but it is evident that the continuity of the sandstones is completely broken up, and that the rocks are in the condition so frequently observed at their contact with the Palæozoic strata, and which is well illustrated by the sketch (fig. 3) of the rocks seen in Allt-Chollie (Colyburn) four miles to the north of Clyne Kirk. At this place the harder beds of the Jurassic sandstones are seen, for a distance of about 100 yards from their junction with the Palæozoic rocks, to be broken up into fragments of various sizes, which lie in every possible position in the midst of a mass of débris formed by the crushing of the softer beds. This appearance was well described by Sir Roderick Murchison at this and several other points*. Returning to the ravine at Clyne Kirk, we find that at some little distance from the junction with the Silurian the beds of sandstone (*b*) and of black argillaceous sand (*c*) are capable of being traced, and are seen to be bent into sharp folds accompanied by slight dislocations. The disturbance of the Jurassic beds diminishes as we remove further from their junction with the Palæozoic rocks.

Between Clyne Kirk and Braamberry Hill the Secondary strata are concealed; but they probably lie in a series of long curves, in some cases broken across by faults, as illustrated by the section (fig. 4, which is drawn to scale) exposed in a bluff on the north side of the river Brora, where the rocks consist of marine sandy clays of Middle Oxfordian age. At Braamberry Hill the sandstone strata, which overlie the clays just mentioned, form an anticlinal, the rocks of which, owing to their superior hardness, resisted denudation; and thence to Brora, as seen in the gorge of the river, the strata

* Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2. pp. 304 and 307; *ibid.* pt. 3. p. 354, &c.

lie with a dip gradually diminishing in amount till it does not exceed 4°*.

The section just described in detail may be regarded as typical; and the relations exhibited by the Jurassic strata here are found to characterize them wherever they appear in the north-east of Scotland. They almost everywhere offer evidence of considerable disturbance and faulting. At the points furthest removed from their contact with the Palæozoic rocks, this disturbance is at its minimum; but as we approach these latter, the angle of dip is found to increase, the folds become shorter and sharper, and the dislocations more numerous, while at the actual junction of the two series of strata the younger ones are often crumpled and crushed in the most remarkable manner.

§ 2. *Relations of the Strata North of the typical line of Section.*

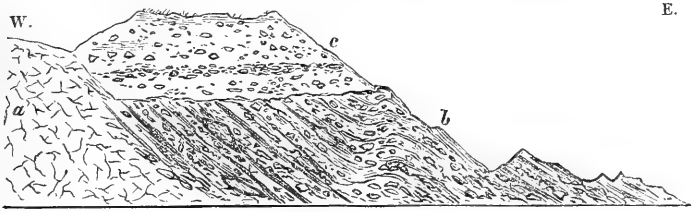
Silurian strata with characters similar to those already described, and containing veins of white quartz, red granite, &c., are found rising to a height of from 500 to 600 feet between the burns of Clyne Kirk and Kintradwell, in the latter of which they are again seen traversed by veins of quartz and felspar, the latter sometimes decomposed into kaolin. I am indebted to Captain Houston, of Kintradwell, for guiding me to these sections. At the openings of the ravines of Achrimsdale, Clyne-Milltown, and the small nameless burn just north of Kintradwell there are exposures of the Jurassic strata; but the contact of these with the Silurian strata is not seen. The interesting section of Allt-Chollie (Coly-burn) has been already described; and in Allt-na-cuil and some smaller ravines to the north, though the actual junction is not exposed, the Jurassic strata are evidently greatly disturbed near their contact with the Silurian.

Near the Lothbeg river and from that point northwards the Silurian gneiss passes into or is replaced by the beautiful red, often porphyritic granite, which covers a considerable area on the confines of Sutherland and Caithness, and forms the great mass of the Ord. Along this portion of the coast the Jurassic strata are in contact with the granite or with the thin strip of Middle Old Red Sandstone (Caithness flags) which flanks it for a distance of five miles, and which will be more particularly noticed hereafter. Between Lothbeg and Helmsdale the strip of Oolitic rock, which is from a quarter of a mile to half a mile wide, is cut through by a number of brooks; and in some of these, especially in Allt Cuil-nan-Gabhar (Culgour Burn), Wester Gartie Burn, Midgartie Burn, and Allt-gharashtiemore (Garty-more Burn), the rocks, as they approach the line of their junction with the Old Red strata, are seen to be more and more disturbed. About Helmsdale the coast is formed by the granite, the Jurassic strata having been wholly denuded away; and north of that town the latter form only a very narrow strip, which is cut through in many places by small inlets of the sea and deep ravines. Some-

* See also Murchison in Trans. Geol. Soc. 2nd ser. vol. ii. part 3. p. 55.

times the cliff is formed of granite, and the Jurassic beds are only seen in a violently contorted state in the reefs on the shore; at other points a mass of Oolitic strata highly inclined appears as if attached to the face of a precipice of granite; while again low promontories projecting from the mountains of granite which come down to the shore are seen to be composed of the same greatly disturbed beds. The most noteworthy example of this kind is afforded by the Dunglass, or Green Table, a peninsular mass, composed of highly inclined Oolitic rocks capped by Boulder-clay, which, projecting from the granite* mountain of the Ord, forms the boundary between the counties of Sutherland and Caithness. This singular spot, of which I have given a section (fig. 5), formed the appropriate lo-

Fig. 5.—*Section at Dunglass (Green Table Point).*



a. Granite of the Ord.
b. Upper Oolite—"Brecciated beds."
c. Boulder-clay.

cality of an ancient settlement in the Stone age, as I am informed by my friend Mr. Joass. North of the Green Table the Jurassic strata are found in the county of Caithness, in a patch of highly inclined rock exposed only at low water.

The remarkable features exhibited by the reefs of these rocks exposed on the shore, where by their sudden variations in dip and strike they clearly manifest their crushed and crumpled condition, have been well described by Sir Roderick Murchison, and are illustrated by the changes of dip which he has recorded on his map†. The striking appearances which these reefs present are greatly heightened by their being composed of those wonderful "brecciated beds" to which more particular attention will be directed in the sequel.

§ 3. *Relations of the Strata South of the typical line of Section.*

The peculiar Silurian rock of Clyne Kirk is seen again in a ravine

* That the great mass of this granite is of very ancient date, and that it has even furnished materials to the Old Red Conglomerate, there appears to be no reason to doubt. Sir Roderick Murchison has pointed out that it could not have been in a molten condition since the Jurassic period; for the rocks of that age, though greatly disturbed, are never metamorphosed or penetrated by veins. Below the bridge at Lothbeg, a section, unfortunatěly somewhat obscure, exhibits veins of granite apparently proceeding from the mass of the Ord and traversing Old Red Sandstone strata. Can it be that we have evidence here of the formation of a granite at the same point at widely different periods?

† Trans. Geol. Soc. 2nd ser. vol. ii. part 2. plate xxxi.

to the southward, and between it and Loch Brora, and at a number of small exposures along the mountain-side. They are also seen on the sides of Loch Brora, wherever the streams have cut sufficiently deep to pass through the thick masses of moraine-matter which mask the flanks of the mountains on either side of Strathbrora.

South of the Loch we find in the Allt-Duchary * an admirable exposure of the metamorphic (Silurian) strata, which here consist in parts of a rock like that of the Clyne-Kirk gorge, but in other parts of red and gray fine-grained gneiss, penetrated by veins of red granite, and identical in character with the great mass of the Silurian strata of the district.

The next point at which a section is cut through the great mantle of glacial detritus which covers the country is in the Sputie Brook. Here the Jurassic sandstones, which are tolerably well exposed at several points about Uppat, are seen in the bed of the brook; and at a short distance above, the Old Red Sandstone and Conglomerate are found *in situ*, having been brought to a much lower level than near Loch Brora by the southerly dip of the strata, which seems to be here greatly increasing in amount; so that the Old Red nearly or quite overlaps the Silurian at this spot.

At several points above Uppat and Dunrobin the Jurassic sandstones and clays are found dipping at considerable angles, but no actual junction of the Primary and Secondary rocks is exposed. It is evident, however, that the Jurassic strata lie against the Old Red Sandstones and Conglomerates, and that near the line of contact they are greatly disturbed; in one place they are seen dipping N.E. 15°, while at a distance of about a quarter of a mile they dip S.W. 30°. These sections are observed in sandstone pits opened in the great deer-forest above Dunrobin Castle; but here the surface of the country is so greatly concealed as to render hopeless the task of tracing out in detail the curves and dislocations of the strata.

In Dunrobin Glen the Old Red Sandstone strata show considerable signs of disturbance. Triassic strata appear, as will be hereafter described, lower down the glen; but no actual contact with the Old Red is seen. At Rhives, near Golspie Inn, and in the cliff and on the shore between Dunrobin and Golspie the same Secondary rocks occur; and these are the last localities at which they have been detected in the county of Sutherland. Southward the beds of the Lower Old Red Sandstone are by their dip brought down to the sea-level; and at the extreme southern extremity of the county of Sutherland, higher and fossiliferous strata of the same system make their appearance †.

The shores of the Moray Firth, with those of the several inlets which open into it, namely Loch Fleet, Dornoch Firth, Cromarty Firth, and Inverness and Beauley Firths, are almost wholly composed of the various strata of the Old Red Sandstone, which succeed one another in a regular manner, and with usually slight dips. But

* Trans. Geol. Soc. 2nd ser. vol. ii. pt. 3. p. 355.

† Murchison, Quart. Journ. Geol. Soc. vol. xv. (1859) p. 398. Joass. *ibid.* vol. xxv. (1869) p. 318.

along a line striking N.E. and S.W., and passing through the town of Cromarty, the metamorphic strata of Silurian age are upheaved; and this movement has been attended with great disturbance of the Old Red Sandstone strata, which, in the neighbourhood of the gneissose, quartzose, and schistose rocks of the Silurian, are seen lying at high inclinations and with numerous folds. The remarkable ridge of metamorphic rocks is cut through by the present entrance to the Cromarty Firth *, and forms those striking headlands the North and South Sutors of Cromarty. The length of the ridge of Silurian rocks is about nine miles; but certain masses of granite which appear to the S.W. may probably be considered a continuation of it. A glance at the position of this ridge of hard rocks will suffice to show to what an extent the existence and form of the two great eastern peninsulas of Ross-shire, Easter Ross and the Black Isle, have been determined by it.

Lying against this ridge of upheaved and disturbed strata we find on the shore three of the patches of Jurassic strata already referred to, namely those of Port-an-Righ, Cadh'-an-Righ, and Eathie Bay. Situated in small recesses of the coast, between headlands of the harder rocks, these patches, which have already been denuded away to a level below that of high water, are evidently the last vestiges of a tract of land which once fringed the high lands of Ross, in the same manner as the low Oolitic district in the south-west of Sutherland now forms a border to the mountains of that county. No one can study these two remarkable and interesting districts without being struck by the fact that here we have a repetition of the same phenomenon, produced by the action of the same succession of causes, but exhibited to our study at two different stages of its history. The two districts mutually explain one another; and it is evident that while on the one hand the south-east coast of Ross must once have exhibited a tract of low-lying land composed of Jurassic strata like that of Brora, this last must at some future period be reduced, by the continued action of existing causes, to a condition analogous to that of the former.

About a mile southwards from the village of Shandwick there appears the first of the patches referred to †. The strata are seen only at low water, and then present a singular appearance: they are bent into long folds and dip seawards at a considerable angle; and being composed of indurated shales with a few harder bands of argillaceous limestone, they have been worn into a series of step-like ridges, which have been not unaptly compared by Sir Roderick Murchison to the seats of an ancient amphitheatre. These strata are also broken up by a number of small transverse faults, which have produced lateral displacement of the beds. The relations of these strata to those of the Old Red Sandstone against which they lie are illustrated by the plan and section, figs. 6 and 7.

* See Murchison, Trans. Geol. Soc. 2nd ser. vol. ii. pt. 3. p. 355. Geikie, 'Scenery of Scotland,' p. 132.

† First described by Sir Roderick Murchison, to whom it was pointed out by Sir George Mackenzie. Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2. p. 307.

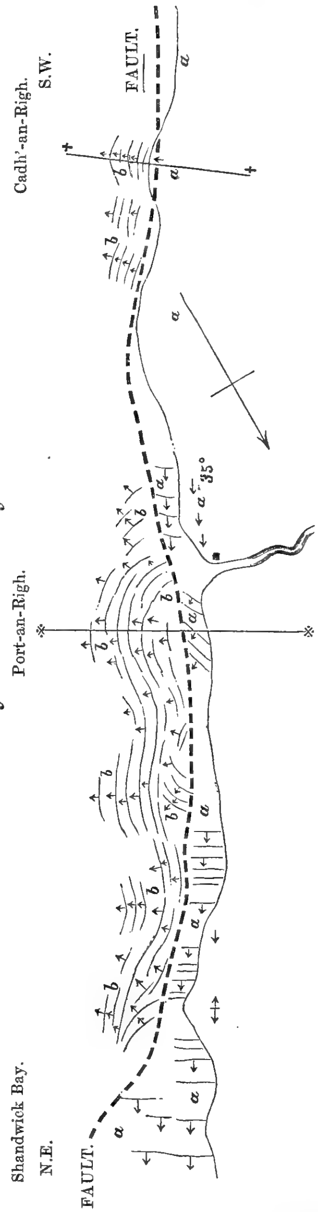


Fig. 6.—*Plan of the Reefs of Secondary Rocks exposed at low water on the shores of Easter-Ross, between Shandwick Bay and Cadh'-an-Righ.*

a. Old Red Sandstone and Conglomerate. *b.* Middle Oolite clays and limestones. ** Section, fig. 7. †† Section, fig. 8.

At less than half a mile southward, but quite separated from the last, we find the second patch of Jurassic strata, that of Cadh'-an-Righ. It is in part composed of indurated shales, similar to those of Port-an-Righ; but underneath these appear freshwater or estuarine beds of clay, sandstone, and coal. Their relations to the Old Red Sandstone against which they lie, but to which, as at Cadh'-an-Righ, they are quite unconformable both in strike and dip, are shown in the section, fig. 8.

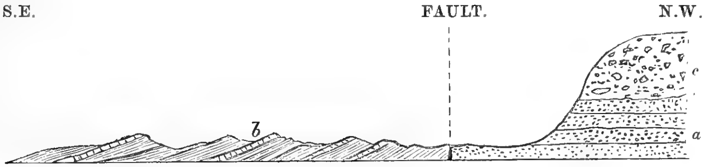
I am not aware that any patch of the Secondary strata *in situ* has been detected to the south-west over the next seven miles. The numerous fragments of these rocks thrown up on the shore, however, render it not improbable that such beds may exist in some of the submerged rocks and skerries which abound along this coast.

In Eathie Bay occurs another interesting patch of Jurassic rocks, which, first pointed out by Sir Roderick Murchison *, has been frequently illustrated in the writings of other geologists, especially those of the late Hugh Miller. As in the last two instances, the beds are only seen during low water; they are composed in one part of alternations of shales and argillaceous limestones, with some beds

* Trans. Geol. Soc. vol. ii. pt. 2. p. 307.

of white sandstone at the base, and in another part of clays and argillaceous grits, with much vegetable matter. They lie in part

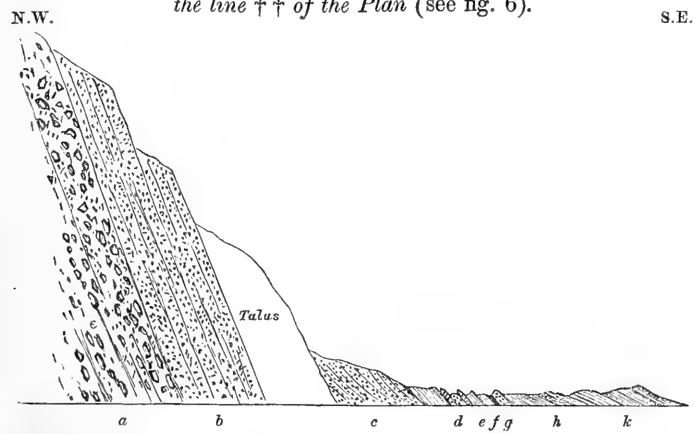
Fig. 7.—*Section across the Reefs at Port-an-Righ, along line* * * *of the Plan* (see fig. 6).



a. Beds of Old Red Sandstone, dipping N.E.
b. Shales and limestones of the Middle Oolite, dipping S.E.
c. Boulder-clay, capping Old Red Sandstone in the cliffs.

against the contorted Silurian rocks, and in part against the highly inclined strata of the Old Red Sandstone, though the actual contact

Fig. 8.—*Section across Shore and Reefs at Cadh'-an-Righ, along the line* † † *of the Plan* (see fig. 6).



Old Red Sandstone.
- *a.* Old Red Conglomerate.
- *b.* Old Red flaggy sandstones.
- (Talus.)

Lower Oolite.
- *c.* White sandstones and light blue clays (estuarine).
- *d.* Alternations of variegated clays, sandstone, and argillaceous limestone (freshwater fossils).
- *e.* Shelly bands and clays (mixture of freshwater and marine shells and numerous plant-remains).
- *f.* Thin coal-seam.

Middle Oolite.
- *g.* Sandstone with many marine fossils ("Roof-bed").
- *h.* Sandy clays with marine fossils.
- *k.* Dark blue clays with septaria (marine fossils).

is concealed by the shingle of the beach. One of the shafts (the northern one) sunk by an unfortunate speculator, who hoped to find

coal here, appears to have commenced almost on the line of junction, and, after passing through a small thickness of the Oolitic rocks,

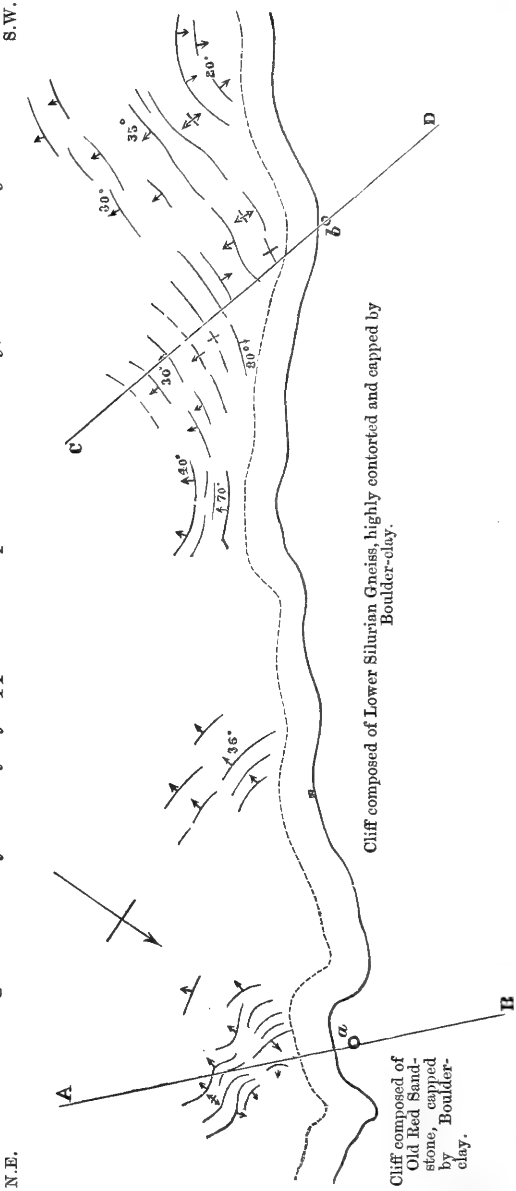


Fig. 9.—*Plan of the Reefs of Upper Oolite exposed in Eathie Bay, near Cromarty.*

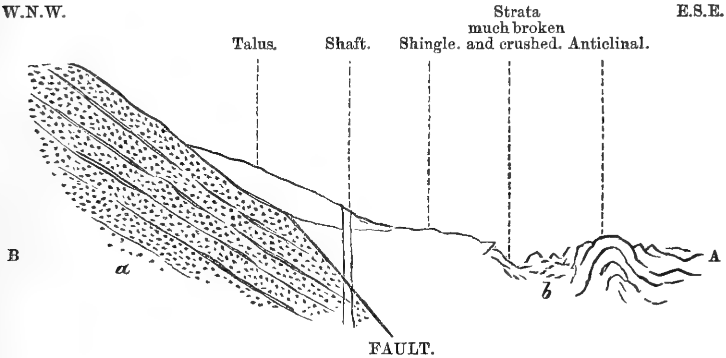
a. Shaft passing through Upper Oolite beds into Old Red Sandstone.
b. Shaft in Upper Oolite beds, more than 100 feet deep.

A B. Section, fig. 10.
C D. Section, fig. 11.

entered the sandstones of the Old Red. The other pit was then

commenced further to the south and a little more removed from the line of junction, but still in close proximity to the great mountain-cliff of contorted Silurian rocks which form "the High land of Eathie;" it is said to have been carried to a depth of more than 100 feet in the shales and limestones of the Oolite.

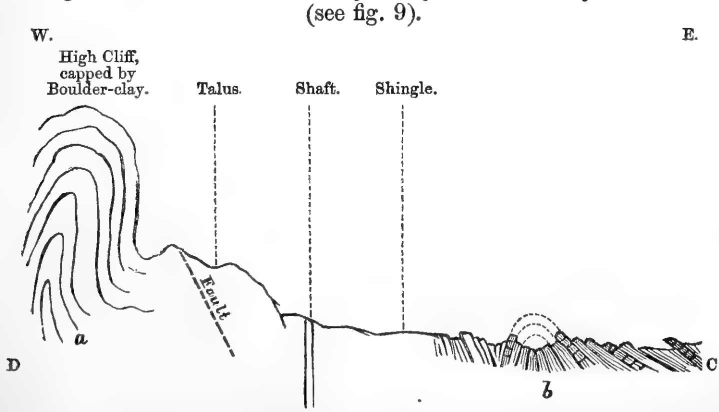
Fig. 10.—*Section at Eathie Bay along the line* A B *of the Plan* (see fig. 9).



a. Old Red Sandstone. *b.* Upper Oolite Shales and Grits.

A careful examination of the reefs on the Eathie shore, which dip at various high angles, and are often perfectly vertical, shows that

Fig. 11.—*Section at Eathie Bay, along the line* C D *of the Plan* (see fig. 9).



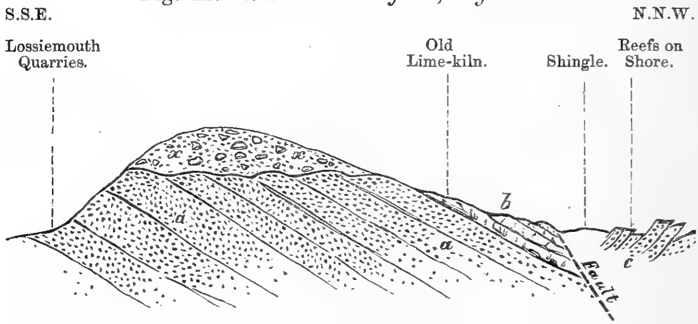
a. Lower Silurian Gneissose rocks &c.
b. Upper Oolite Shales, Limestones, &c., with pseudo-dykes.

they are the denuded edges of a series of strata bent into a number of sharp folds and contortions, as is illustrated in the sections,

figs. 10 and 11. The plan (fig. 9) shows the general relations of the strata exposed in Eathie Bay. At one point the rocks of the Upper Oolite, near their junction with the Old Red Sandstone, present the same crushed appearance that is so common, under similar circumstances, with the strata in Sutherland.

Crossing to the south side of the Moray Firth we find at Stotfield, in the county of Elgin, a patch of sandstone strata, to which my attention was first called by Dr. Gordon, and which has yielded to the patient researches of Mr. Grant, of Lossiemouth, a very considerable fauna. These beds, as will be shown in the sequel, are of Lower-Oolite age; and they are clearly seen to be faulted against the strata composed of calcareous and arenaceous rocks of Triassic age (see section fig. 12) *. It is possible that the whole of the reefs at this

Fig. 12.—*Section at Stotfield, Elginshire.*



x. Boulder-clay.
a. "Reptiliferous Sandstone." } Trias.
b. "Cherty rock of Stotfield." } Trias.
c. Greenish and reddish sandstones with shells (Lower Oolite).

point, and of the outlying rocks called Halliman Scars, are of the same age, and that their red colour is an accident due to similar causes to that which has produced the red colour of many of the reefs of Oolitic rock on the shore of Sutherland. These beds, however, have as yet yielded no fossils; and future researches may show that they are of a different age, and have been brought into their present position by another fault.

The promontory of Burghead is formed by a series of sandstones, grits, and conglomerates which, as Professor Harkness has well shown, is faulted against the great mass of the Reptiliferous sandstone † which forms the coast-ridge here. The similarity of position

* Since this paper was read, Prof. Ramsay has kindly intrusted to me the note-book used by him during his examination of the north of Scotland in 1859. It affords me no small satisfaction to find that in this, as in a number of other points, my own conclusions are entirely confirmed by the unpublished observations of my former teacher. Prof. Ramsay recognized the existence of a great fault at Stotfield, and represented it in a section identical in all essential points with my own.

† Quart. Journ. Geol. Soc. vol. xx. (1864) p. 436, fig. 3.

and relations of this patch to that of Stotfield, and the nature of the rocks which compose it, so greatly resembling the coarse grits and conglomerates of part of the unfossiliferous Lower Oolites of Sutherland, strongly suggest that the Burghead beds may be of the same age as those of Stotfield; but hitherto, unfortunately, no fossils have been found in the former.

At various points throughout the peninsula which lies between Burghead and Stotfield Heads, interesting strata of Triassic age are exposed, as will be described hereafter. The district is traversed by a series of great faults ranging N.N.E. and S.S.W., as shown by Professor Harkness *. By far the larger part of the area being deeply covered with drift, above which only a few ridges of the hardest rocks appear, it is possible that other patches of the Jurassic rocks may be preserved within it, though hidden from our observation; in the Boulder-clays of the district fragments and immense transported masses of the Liassic and Oolitic rocks are particularly abundant.

Having now described the general position and relations of the several patches of Secondary strata in the north-east of Scotland, it is necessary to refer to a peculiar phenomenon presented in them, and which has been already described by several geologists. I refer to the existence of *pseudo-dykes* among them. These present all the external forms of dykes of igneous rock, running in a more or less vertical direction across the several beds, and sending off various branches and offshoots in their course. When the nature of the rock of which they are composed is examined, however, it is found that, instead of being composed of materials of igneous origin, the rock is certainly an aqueous one, an indurated sandstone or a calcareous grit. These pseudo-dykes occur at Eathie †, Kintradwell ‡, and in the Brora coal-field §. Two important facts tending to elucidate this subject were noticed by Hay Cunningham and Hugh Miller respectively. The former showed that in the fine example at Kintradwell, fragments of carbonaceous matter occur, and that these are arranged, not horizontally as in the associated *beds*, but vertically and parallel to the sides of the dykes ‖; the latter found an Oolitic shell enclosed in one of the dykes at Eathie ¶. During my own survey of the district, the only fact of importance which I was able to add to those accumulated by previous observers was, that at Eathie some of the most important of these pseudo-dykes run along the axes of the anticlinal folds of the contorted strata.

These pseudo-dykes always traverse greatly disturbed or contorted strata. That they have been filled from above is clear, as pointed out by Hugh Strickland; but that the fissures in the soft

* Quart. Journ. Geol. Soc. vol. xx. (1864) p. 431, fig. 1.

† See H. E. Strickland in Trans. Geol. Soc. 2nd ser. vol. v. p. 599.

‡ Murchison, Trans. Geol. Soc. 2nd ser. vol. ii. p. 304. Cunningham, 'Geognosy of Sutherlandshire' (1839), p. 36, plate vii. fig. 2, note G.

§ Murchison, Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2. p. 301.

‖ *Op. cit.* p. 36.

¶ Sketch-book of Popular Geology (1859), p. 305.

shales which they traverse could have remained open and been filled from the water of the sea which deposited the overlying rocks, like the Liassic veins in the Carboniferous limestone of the Mendips so admirably described by Mr. C. Moore *, seems altogether incredible. The explanation of the phenomenon which I would suggest is as follows:—that at the time when the upheaval which produced the fractures took place, the shales were already covered by beds of soft and unconsolidated sand, and that, as the fissures gradually opened, the sand as gradually found its way down into the interstices; finally the sand, both in the beds and the fissures, became consolidated into a hard rock.

§ 4. *Summary of Observations and Conclusions as to the Relations of the Palæozoic and Mesozoic strata of the North-east of Scotland.*

From the details which I have now given, I believe that the following propositions on the subject may be considered fully established.

(1) The Secondary rocks lie indifferently against all the members of the Lower Palæozoic series, from the Lower Silurian and associated granites up to the Upper Old Red Sandstone.

(2) The Secondary strata which are thus in contact with the Palæozoic rocks are of very various ages, from the Trias to the Upper Oolite inclusive, and contain representatives of all the subdivisions of the Jurassic series, except perhaps the Upper Lias.

(3) There is a total absence in the Jurassic series of strata made up of fragments of the rocks against which they repose; and, on the other hand, the conglomerates, which are by no means rare in that series, are made up of fragments of rocks totally different from these.

(4) There are no indications whatever in this series of Secondary strata that, as we approach the Palæozoic rocks, we are coming to an old shore-line.

(5) The Secondary rocks exhibit signs of having undergone great disturbance, being bent into numerous folds, broken up by many faults, and traversed by fissures filled with materials from above; their fossils are also much more frequently distorted by pressure than those of the equivalent strata in England.

(6) The evidence of disturbance and dislocation in the Secondary strata increases as we approach the Palæozoic rocks, till at last the beds of the former are often found in a completely crumpled and crushed condition at the points of contact.

All these facts point to one conclusion—namely, that the Secondary strata of the north-east of Scotland owe their present positions and their consequent remarkable preservation from the denudation which has removed such enormous masses of contemporary deposits in this area, to *great faults*, which have thrown them down, probably several thousands of feet, below their original level. I find that Prof. Geikie has already arrived at this conclusion with regard

* Quart. Journ. Geol. Soc. vol. xxiii. (1867) pp. 483, 491, &c.

to the patches in Ross *; and Prof. Ramsay informs me that, when he examined the Brora district some years ago, he was led to adopt the same views with regard to it.

§ 5. *Confirmations of the above conclusions concerning the Relations of the Palæozoic and Mesozoic Strata.*

I have now to point out two very remarkable and interesting phenomena, which, while they are on the one hand altogether anomalous and inexplicable, except on the hypothesis that the two series of rocks have acquired their present relations through the agency of great faults, are, on the other hand, seen to be in most complete harmony with the inferences to which all the other facts have led us.

It will be shown hereafter that the Upper Oolite beds in portions of this district are almost wholly made up of derived blocks. These blocks so precisely agree in mineral character with the Caithness Flagstones and associated beds of the Middle Old Red Sandstone, that Sir Roderick Murchison was evidently strongly inclined to refer them to this source. One fact, however, appeared to offer insuperable difficulties to accepting such a conclusion. The rocks which now appear in closest proximity to the Secondary strata in question are the Ord Granite, and the conglomerates and sandstones of the Lower Old Red, while the Middle Old Red Sandstones were then known only at a considerable distance. Sir Roderick pointed out the remarkable fact, which subsequent observations have completely confirmed, of the total absence of fragments of those well-marked and most easily recognizable rocks (the Ord Granite and the Old Red Conglomerate) in the "brecciated beds" †.

So fatal did Sir Roderick consider this fact to the hypothesis that the blocks in question were derived from the Palæozoic strata, that he found himself compelled to abandon it; but it is with evident doubt and reluctance that he resigns the theory in question in favour of another.

As I shall have to show more fully hereafter, the fact that these blocks in the "brecciated beds" are derived, and that they are of Middle Old Red Sandstone age, is put out of all question by the discovery in them of the remains of the characteristic fishes. The difficulty pointed out by Sir Roderick Murchison reappears therefore with its full force.

If, however, we admit that the present position and relations of the Primary and Secondary strata are due to a great fault, this startling difficulty at once disappears; for the thick series of the Middle Old Red Sandstone, so magnificently developed in Caithness, where it has escaped denudation, might then have formed the lands bounding the Oolitic sea, while the granite of the Ord and the conglomerates and sandstones of the Lower Old Red were buried below thousands of feet of newer rocks.

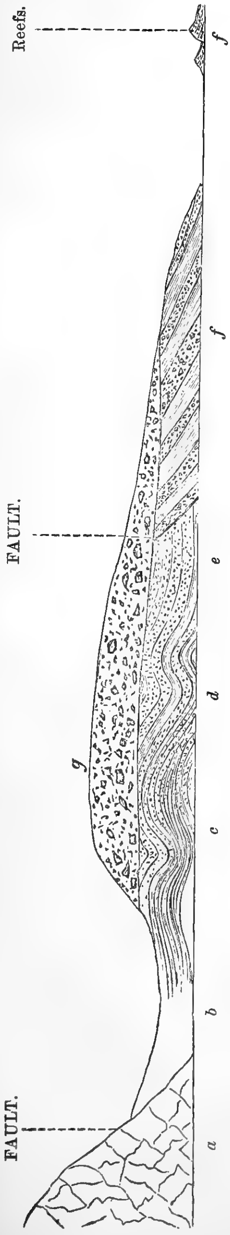
* Scenery of Scotland, p. 177.
† Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2. pp. 306, 307.

Still more striking is the other phenomenon I have alluded to as confirming the existence of the great faults in question. As has already been pointed out, the highest mountains in the south-east of Sutherland are capped by the beds of the Lower Old Red Sandstone and Conglomerate, which, as we follow them towards the north, are found dipping under the enormously developed strata of calcareous and bituminous flagstones with associated sandstones, marls, &c. constituting the Middle Old Red Sandstone, and occupying so large a portion of the county of Caithness. Now no geologist can for a moment glance at the present relations of these strata without perceiving what Sir Roderick Murchison so clearly pointed out—namely, that the various patches of Old Red Conglomerate and Sandstone are the remaining vestiges of a widely spread formation which was doubtless once covered by deposits of Middle Old Red Sandstone age, forming the connexion between the great fish-bearing beds of Caithness and Ross *. Hitherto, however, not a trace of the Middle Old Red or Caithness Schists had been found in the county of Sutherland. During my examination of the district, I had the good fortune to discover a small but well-marked patch of these strata, the position of which was such as to be *absolutely inexplicable on any hypothesis but that of the existence of great faults*, and to afford the very strongest support, I may say the most triumphant confirmation, of those conclusions as to the relations of the strata which have been deduced from other facts.

The section which best illustrates the position and relations of the fragment of the Caithness flags referred to is exposed in the Allt-gharashtiemore (Gartymore Burn), north of the village of Port Gower; but other less complete sections enable us to trace the extent of this singularly isolated patch of the Middle Old Red Sandstone, and to show that it is about five miles long and from a quarter of a mile to half a mile broad. The accompanying section (fig. 13) clearly illustrates the relations of this wonderfully preserved fragment of a great formation. It is evidently enclosed between two great faults, by one of which it is brought into apposition with the granite of the Ord, which is probably of Lower Silurian date, while, by the other, strata of Upper Oolite age have been let down against it. The well-marked and highly distinctive characters of the beds of the Caithness Schist leave no room for doubt as to the correctness of the identification of the strata of this isolated patch. The Rev. J. M. Joass, who kindly examined this section with me, and whose intimate acquaintance with the Old Red Sandstone of the north of Scotland gives such weight to his opinion on the subject, informs me that he has not the slightest hesitation in considering them part of the Middle division of that formation, and that he has little doubt they belong to the lower part of that division. The strata, as might be expected from their position between the two great faults, are greatly disturbed and crumpled. They are seen again, but more

* *Vide* Murchison, Quart. Journ. Geol. Soc. vol. xv. (1859) p. 393 *et seq.*

Fig. 13.—*Section at Allt-Gartymore near Port Gower, Sutherland, showing double fault.*



a. Granite of the Ord (Lower Silurian?), capped in the interior by Lower Old Red Sandstone and Conglomerate.
b. Strata concealed.
c. Flaggy, calcareous, and highly micaceous beds.
d. Red and green argillaceous beds, with interstratified red and white mottled sandstone.
e. Light-coloured sandstone, with pink spots and patches of greenish clay.
} Old Red Sandstone, Middle Division (Caithness Flags).
f. "Brecciated beds," alternating with finely laminated sandy clay, with lignites &c. (Upper Oolite).
g. Boulder-clay.

obscurely, in the gorges cut through the drifts by the Easter and Wester Garty Burns and the Lothbeg river *.

Here then we have proof that the great fault which has brought about the juxtaposition of the Primary and Secondary strata in Sutherland has, through about five miles of its course, become double, the strata on the south-east having been let down by two steps instead of one; and thus a strip of an intermediate formation has been preserved. Similar phenomena, on a smaller scale, are familiar to all field-geologists who have mapped greatly faulted districts.

We have thus shown that the preservation of the interesting patches of Secondary strata in the north-east of Scotland is entirely due to the concurrence of a series of favourable accidents. First among these (both in order of time and in importance) we must rank those great dislocations which have brought the strata in question into apposition with rocks of so much greater hardness and capability of resisting denuding forces. The general strike of these great faults is from N.E. to S.W.; and they doubtless constitute a portion of the results of that great and long-continued series of disturbances which have so largely contributed to the production of the physical features of this island. The influence of this great

* Since my return to England, my indefatigable friend Mr. Joass informs

system of subterranean disturbance is seen, not only in the general parallelism of the great synclinal and anticlinal folds and the faults of the strata in Scotland, and the consequent position and features of her mountain-ranges, valleys, rivers, and lochs, together with the outlines of her coasts and islands, but equally in the direction of the strike of the outcrops of the long series of successive geological formations in England. The facts of the existence and long continuance of this great system of disturbance, and the important results produced by it, are now admitted by all geologists, whether they regard such subterranean forces, with the late Sir Roderick Murchison and the Duke of Argyll, as the *immediate* cause of the physical features of the country, or, with Professors Ramsay and Geikie *, as only directing and modifying the really efficient and direct cause of those phenomena—namely denudation.

A review of the general position and relations of the strata of the north-east of Scotland appears to indicate that, over the tract now occupied by the Moray Firth, the Secondary strata were let down among the Palæozoic rocks by a series of parallel faults ranging N.E. and S.W., and that, by the slow action of denuding forces, the great mass of these strata has been removed, a few minute patches alone escaping. The general form of this vast inlet and the position of the peninsulas which project into it have been determined by these great faults; and it is probable that extensive deposits of Secondary age still exist beneath its comparatively shallow waters.

To some the hypothesis contained in the foregoing pages may, at first sight, appear startling—namely that, over large areas of the Highlands, Secondary strata to the thickness of from 2000 to 3000 feet (not to notice the Cretaceous and Triassic rocks) once existed, and that all of these, with the exception of a few minute fragments, have been removed by denudation. But those who have seen how many thousands of feet of apparently almost imperishable rocks, like the Laurentian gneiss, the Lower Silurian quartzites, and the Old Red conglomerates, have evidently been removed over vast areas in the Highlands, as indicated by the truncation of curved strata and the position of outlying patches, will readily admit the facility with which the same causes, under equally favourable conditions, would have swept away the comparatively soft masses composing the strata of the Secondary series.

III. *Description of the Series of Secondary Formations in the North-east of Scotland.*

An admirable topographical description of the areas occupied by

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me that a portion of a *Coccosteus*, a characteristic fish of the Middle Old Red, has recently been obtained from this isolated patch in Sutherland.

* Professor Geikie considers that the fault which has thrown down the patches of Oolite on the Ross-shire coast may be only a continuation of that great dislocation which certainly traverses the line of the Caledonian Canal ('Scenery of Scotland,' p. 177); if not continuous with, it is certainly parallel to, that great fault.

the Mesozoic strata in the north-east of Scotland having been already given by the late Sir Roderick Murchison, and the important question of the relation of these strata to the Primary rocks fully discussed in the foregoing pages, we may now proceed to a detailed account of the characters presented by each of the Secondary formations as developed in this district. These we shall treat of in chronological order. With regard to the sequence, mineralogical characters, and fossils of the subdivisions of the Mesozoic strata we have three kinds of evidence, which are of very different degrees of value.

1st. The connected series of sections, sufficiently clear though often of limited extent, of the beds seen *in situ* in Sutherland (see Table I.).

2nd. The sections in the more isolated patches, also *in situ*, at other points around the shores of the Moray Firth.

3rd. The large transported blocks and numerous scattered fragments of the various Secondary rocks included in the Boulder-clay of this part of Scotland (see Table II.).

§ 1. *The Trias.*

On the southern side of the Moray Firth, between the headlands of Burghead and Stotfield, a tract of land projects considerably to the northward of the general line of the coast; at a period geologically very recent, part of this district constituted an island in the Firth, and till late historical times it remained almost separated from the mainland of Scotland by the Loch of Spynie. Within this promontory and in the country bounding it on the south there is developed a formation which, on account of the apparent discrepancy between the stratigraphical and palæontological evidence as to its age, has attracted much attention and occasioned keen debate among geologists. Under these circumstances, it may be advantageous to distinguish carefully between the conclusions (concerning the relation of these beds) which are the result of direct observation, and therefore not open to question, and such as have been arrived at from inferences of a general character and are still the subjects of controversy.

The formation in question consists of two members, the upper calcareous, the lower arenaceous.

A. "*The Cherty Rock of Stotfield.*"—Great differences of opinion have existed among geologists as to the correct designation for this rock. Sir Roderick Murchison calls it a "cornstone," but at the same time points out that it presents characters which distinguish it from the rocks usually included under that name*. Professor Harkness discards the use of the term "cornstone" and calls it simply a limestone†; while the Rev. W. S. Symonds strongly insists that "cornstone," as applied to this rock‡, is altogether a misnomer, and Mr. C. Moore compares the rock to one which occurs

* Quart. Journ. Geol. Soc. vol. xv. (1859) p. 431.

† Ibid. vol. xx. (1864) p. 431 &c.

‡ Edinburgh Phil. Journ. New Ser. vol. xii. (1860) p. 96.

in the Trias on the flanks of the Mendips *. All observers, however, agree that the rock is of a remarkably peculiar and almost *unique* character, Mr. Symonds calling it "*a most distinguishable rock.*" To obviate confusion, I use a term which does not involve any theoretical views, and which was first applied to it by Dr. Gordon of Birnie †, who has done so much for the elucidation of the geology of this difficult district, both by his own observations and by constantly placing his great local knowledge at the service of other investigators.

The mass of the Stotfield rock is composed principally of calcareous and siliceous materials. The former is usually a hard, compact, impure limestone, of a cream-colour, which in places becomes crystallized and exhibits fine examples of calc-spar, with fibrous and radiated carbonate of lime. The latter forms nodules and cavernous masses imbedded in the former, and consists of compact cherty or flinty material, occasionally exhibiting the banded structure of jaspers and agates, and containing drusy cavities incrusted with crystals of quartz or mammillated coatings of chalcedony. With these principal materials there is often associated an amorphous argillaceous mineral, of a greenish colour; while beautifully crystallized galena, pyrites, and blende are sometimes disseminated through the mass as accidental ingredients.

The total thickness of this rock is unknown, its upper portion being always denuded away; but it is said to have been dug to the depth of 30 feet ‡. When exposed to weathering action, the calcareous portion of the rock is removed, and the hard indestructible masses of cherty material remain. Where the rock is covered with Boulder-clay, pits were formerly dug into it; and the most purely calcareous masses being selected, they were burned into lime; but the tendency of the material, when the siliceous portions were not rigidly excluded, to fuse into solid masses in the kiln, and the superiority of the Silurian limestones of Banffshire, have led to the almost total abandonment of these old pits. Several attempts have been made at Stotfield to work the galena, which is associated with this rock there, as also at Inverugie and other points; but, owing to the fact of the metallic ores being disseminated through the mass and not collected into veins, these attempts have proved futile.

The origin of this peculiar rock, *which is altogether destitute of any trace of organic remains*, is a very interesting problem. That its formation must be referred to purely chemical agencies is, I think, in the highest degree probable; but into this question I do not propose to enter, it being sufficient for my present purpose to point out the highly peculiar, if not unique, character of the rock, and the consequent facility with which it can be identified.

B. "*The Reptiliferous Sandstone.*"—This lower division of the formation consists of beds of sandstone, sometimes slightly calcareous, and usually of a pale colour inclining to yellow; it has often grains

* Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 446.
† Edin. New Phil. Journ. New Ser. vol. ix. (1859) p. 15.
‡ Duff, 'Sketch of the Geology of Moray' (1842), p. 23.

of a dark material disseminated through it. Locally, as is so commonly the case with rocks coloured by oxide of iron, it exhibits patches of a pinkish tint. In these sandstones false-bedding abounds, while the true bedding is often very indistinct; the jointing, on the other hand, is usually extremely well-defined; and the combination of these characters gives the rock a peculiar and distinctive mode of weathering, as was pointed out to me by my friend Dr. Gordon.

This rock is almost wholly destitute of organic remains; but at certain points, especially in some of the extensive quarries near Cummingstown, its bedding-planes exhibit ripple-marks, sun-cracks, and tracks of various kinds, including numerous series of foot-prints of very various size and character. At Lossiemouth there is a bed, about 100 feet below the top of the sandstones, which has yielded numerous scales and bones of the reptiles *Stagonolepis*, *Hyperodapedon*, and *Telerpeton*, while of the last-mentioned genus a single specimen (the original one) has been found at Spynie, and some remains of the first-mentioned have occurred at Findrassie. It is a singular and noteworthy circumstance that the foot-prints and reptilian remains are never found together; and in only one instance have they been obtained from the same quarry.

This sandstone rock is very extensively quarried about Cummingstown, Hopeman, Lossiemouth, and Spynie; and most of its beds yield a very valuable freestone, of excellent colour, which can be obtained in blocks of great size. It forms, indeed, one of the principal building-stones of the north of Scotland, and, the quarries being contiguous to the sea, it is exported to considerable distances.

Unfortunately the stratigraphical relations of the formation which we have been describing are almost wholly concealed by the enormous masses of Boulder-clay and other superficial accumulations which prevail to so great an extent in this district. Dr. Gordon, writing in 1859, says—

"Two circumstances tend materially to render the examination of this part of the province of Moray difficult to the geologist. There are such vast accumulations of the Boulder-clay, of the gravels and sandbanks of the drift, and of the débris of ancient sea-margins, that few sections of the underlying strata are fully exposed; and even where they are best seen, there seems to have been so great and so extensive a denudation during the time of their deposition, that a complete or uninterrupted sequence of strata and their beds has not been detected" *.

An admirable description of these various superficial deposits has been given by Mr. John Martin, of Elgin†.

The relation of the calcareous and arenaceous members of the formation we are describing is fortunately perfectly clear; and, indeed, this point has never been disputed. At Stotfield and Inverugie the peculiar calcareous and cherty rock is seen to overlie and pass down into the Reptiliferous Sandstone; and the position of the same strata

* Edin. New Phil. Journ. New Ser. vol. ix. (1859) p. 15.

† Ibid. New Ser. vol. iv. (1856) p. 209.

at Spynie * and other points at which they are seen is such as entirely to harmonize with and confirm this conclusion.

When, however, we seek for information as to the strata which respectively underlie and succeed this formation, we find that the greatest differences of opinion prevail. Nowhere in Elginshire has the Cherty Rock of Stotfield been seen to be covered by any other beds; indeed it is the remarkable indestructibility of that stratum which, as pointed out by Sir Roderick Murchison, has led to the preservation of the several ridges of sandstone, which rise like islands in the midst of a sea of drift. Whenever it is well exposed, as at Inverugie and Linksfield, the upper surface of the Cherty Rock of Stotfield exhibits the most beautiful glacial polishing and striation. The fact that this rock is never found succeeded by any other formation in the Elgin district has been very strongly insisted upon by several authors, especially by Mr. Duff † and Professor Harkness ‡.

Similarly we seek in vain for any clear and undisputed section showing the Reptiliferous Sandstone in overlying contact with any other rock.

As the several exposures of the various rocks in the Elgin district are often miles distant from one another, and the inclination of the beds considerable, views of the most diverse character have been maintained by different geologists as to the relations of the different rocks underlying the drifts in this district, even when they agree in regard to the primary question of their age. In illustration of this it is only necessary to point to the sections of Sir R. I. Murchison § and Professor Harkness ‖ taken along the same line of country.

The rocks which in the Elgin district are developed in the immediate neighbourhood of the disputed formation are proved by the most unquestionable evidence to belong to the Old-Red-Sandstone system; and from the general positions, relations, and dips of the several patches of rock exposed, we should be led to conclude that the strata in question belonged, *if the country were not a greatly faulted one*, to that system.

In support of this view it has been pointed out that in the higher division of the Old Red Sandstone there exist light-coloured arenaceous strata, not very dissimilar in character to the Reptiliferous Sandstone; while the Cherty Rock of Stotfield has been thought comparable to some of those concretionary limestones or cornstones which are not unfrequently found in the Old Red.

On the other hand it is a remarkable fact that, while in almost every quarry opened in these higher beds of the Old Red Sandstone remains, more or less numerous, have been found of the characteristic fishes of that system, the Reptiliferous Sandstone, which has

* See Captain Brickenden's Paper, Quart. Journ. Geol. Soc. vol. vii. (1853) p. 289.

† Sketch of the Geology of Moray (1842), p. 24.

‡ Quart. Journ. Geol. Soc. vol. xx. (1864) pp. 433, 435, 436, &c.

§ Ibid. vol. xv. (1859) pp. 424–428, figs. 1 and 2.

‖ Ibid. vol. xx. (1864) p. 431, fig. 1.

been worked on a very extensive scale, and subjected to the most diligent search, has never yielded a trace of such fossils. Neither has any trace of the reptilian scales or bones been found in any undoubtedly Old Red Sandstone beds. The Cherty Rock of Stotfield, too, is admitted on all hands to differ greatly from any recognized bed of cornstone, and strikingly from that which occurs in the immediate neighbourhood at Foths in the parish of Birnie, and which is of undoubted Old-Red-Sandstone age.

But in a district which is so hopelessly sealed up from the investigations of the field-geologist by overwhelming masses of drift as is that of Elgin, the generalizations founded on the examination of a few exposures of rock, miles apart, lose all their weight, if it should appear that the country has been subjected to great dislocations.

That the strata of the Elgin district have been thus broken up by a series of fractures is, I think, quite indisputable. Indeed I believe that no one acquainted with the area will deny the existence of a number of great faults ranging E.N.E. and W.S.W., and of cross fractures subordinate to these. In proof of this disturbed condition of the strata I would briefly notice the following circumstances.

1. The strata, when examined over the whole district, are found to dip at various angles, and at some points, as the Clashack quarry, are actually seen to be bent into great anticlinal folds.

2. Even in the small exposures of the strata visible, as between Burghead and Cummingstown and on the Findhorn, as pointed out by Professor Harkness*, and near Bishop-Mill as pointed out by Mr. Symonds†, there are indications of the existence of faults.

3. The repetition of strata which are unquestionably the same and have a considerable dip, at distant points (as for example, in the Spynie and Lossiemouth ridges, which are three miles apart), indicates the existence of such disturbance.

4. I may notice that Professor Harkness has pointed out the existence of these great lines of faulting, and has indicated their probable position.

5. Dr. Gordon has noticed the existence of patches of Old Red Sandstone lying at Pluscarden and Rininver in the midst of the Lower Silurian strata ‡, identified in the former locality by the remains of fish, and in both by the marked mineral characters of the beds; and it seems to be impossible to account for the position of these except by admitting that the whole district has been subjected to great dislocation.

Lastly, I have shown that strata, proved by the most unquestionable fossil evidence to be of as recent date as the Lower Oolite, are found at Stotfield faulted against the older strata. The existence of this fault was recognized by Professor Ramsay in 1859.

The conclusion, to which I think all the facts which I have ad-

* Quart. Journ. Geol. Soc. vol. xx. (1864) p. 432, fig. 2, p. 436, fig. 3.

† Edin. New Phil. Journ. New Ser. vol. xii. (1860) p. 97.

‡ Ibid. New Ser. vol. ix. (1859) p. 43.

duced point, is that *in the Elgin district* the formation, which is made up of the two well-marked members the Cherty Rock of Stotfield and the Reptiliferous Sandstone, is altogether *isolated*, and its stratigraphical relations therefore *undeterminable*. I believe that I am supported in this conclusion by those who have made this district the subject of their most constant and careful study.

Under these circumstances a question of great importance arises—namely, whether this remarkable formation exists in any other district, where its relations may be the subject of more successful investigation by the geologist.

The beautiful Ross-shire section of the Old Red Sandstone, which exhibits in a series of cliff-exposures a conformable succession of beds, from the lower conglomerates of the Northern Sutor of Cromarty to the light-coloured sandstone of Tarbet Ness, has been described by Professor Sedgwick and Sir R. I. Murchison*, the Rev. J. M. Joass†, and Professor Harkness‡. The supposition originally put forward by Sir R. I. Murchison, that the highest beds of this section represent the Reptiliferous Sandstone of Elgin, appeared to derive great support from the interesting discovery of footprints in these strata at Portmahomack and Cambus Shandwick, which discovery was made in 1863 by the Rev. J. M. Joass and the Rev. George Campbell§.

But, in spite of this most valuable discovery, I cannot but regard this identification of the strata of Tarbet Ness with the Reptiliferous Sandstone as a very doubtful one. In mineral character the former much more closely resemble the light-coloured sandstones of Upper-Old-Red age both in Elginshire and Sutherland. Too much weight must not be attached to the presence of *footprints*, which might, indeed, have been occasioned by *Amphibians* such as we now know to have existed at as remote a period as that of the Lower Carboniferous. Professor Elliot some years ago discovered what were supposed to be footprints in the undoubted Upper Old Red Sandstone beds of Nairnshire. This circumstance was brought under my notice by Dr. Gordon, to whom I am indebted for so much assistance in the study of this question. The slab on which these markings are seen was presented by Mr. Stables, of Cawdor, to the Elgin Museum; but, from examination of a cast of them, both Professor Huxley and Professor Rupert Jones pronounce these markings to be of exceedingly doubtful origin.

The strongest circumstance, however, against the identification of the Tarbet-Ness sandstones with those of Elgin is the absence at the former place of that most remarkable, indestructible, and easily recognizable stratum, the Cherty Rock of Stotfield. When we consider the manner in which the two members of the formation are always associated in Elginshire, and the fact that the preservation of the sandstones from denudation appears to be in

* Trans. Geol. Soc. 2nd Ser. vol. iii. part i.
† Quart. Journ. Geol. Soc. vol. xix. (1863) p. 506.
‡ Ibid. vol. xx. (1864) p. 437.
§ Ibid. vol. xix. (1863) p. 506.

every instance due to the indestructibility of the overlying cherty rock, the absence of this latter in Ross-shire becomes the more inexplicable. No importance can be attached to the fact which has been pointed out that fragments of the rock are found on the beach near Tarbet Ness, as, owing to their intense hardness, similar rolled fragments are common all round the shores of the Moray Firth.

Although we may reject the evidence of the footprints of Tarbet Ness as supporting the identification of the sandstones of that place with the reptiliferous beds of Elginshire, yet the great interest and importance of the discovery remains. Indeed that interest is greatly heightened if, by the separation of them from the Reptiliferous Sandstone of Elginshire, we are able to remove all reasons for doubting their Old-Red age; for we may, in that case, regard it as proved that beings *higher in the animal series than fishes* existed at as early a period as that of the Upper Old Red Sandstone.

The difficulties in which, as we have seen, the question of the relations of this remarkable formation is involved on the southern side of the Moray Firth disappear, I believe, when we examine it on the northern side of the same Firth. In the county of Sutherland, at a distance of 30 miles from Stotfield, both the members of the formation occur; and the sections, fortunately, are of such a clear character that, while on the one hand they satisfy the observer as to the identity of the rocks on the north with those on the south of the Firth, they, on the other hand, leave no room for doubt as to the true position of these rocks in the geological series.

I am indebted to the Rev. J. M. Joass for first calling my attention to some patches of a peculiar rock imperfectly exposed in the Burn of Golspie. Subsequent study of the district enabled me to trace this rock, partly by small exposures and partly by the exact records of the position of old lime-pits &c. in Farey's Report on the district (to which I have already alluded), through its outcrop of nearly two miles in length to the reefs on the shore between Golspie and Dunrobin, where its relation to the series of Secondary strata is perfectly evident. A careful examination and comparison of the rocks on both sides of the Moray Firth convinced me that this rock was no other than the Cherty Rock of Stotfield, and that it was underlain by a series of sandstones with similar characters to those of the reptiliferous beds of Elgin. My friend Dr. Gordon has since informed me that some years ago, on being shown the isolated patches of rock in the Golspie Burn (concerning the relations of which nothing was at that time known), he at once pronounced them to be identical in character with his "Cherty Rock of Stotfield."

I have already pointed out the highly distinctive characters of this remarkable rock, which characters are exhibited in the most striking manner by the Sutherland deposit. We have the same peculiar cream-coloured limestone, occasionally crystallized, with like irregular cherty nodules, the whole mingled with the same greenish argillaceous mineral. Indeed, when we compare a series of specimens obtained on the northern side of the Firth with one from the southern side, the rocks are found to be absolutely undistinguish-

able. As in Elginshire, the rock near Golspie was formerly burnt for lime; and its use has been abandoned for the same reasons as in that county. The points in Sutherland where the Cherty Rock of Stotfield has occurred are as follows:—

In a wood N.N.E. of Rhives House, where it was dug and burnt (*Farey*). The pit is now abandoned.

In the romantic Glen of Dunrobin, by the side of the Golspie Burn, there are two exposures of the rock, the strata evidently having resisted denudation, as in the neighbourhood of Elgin, and appearing under a great mass of superincumbent Boulder-clay. The more northerly of these exposures exhibits the highly calcareous variety of the rock, perhaps forming its upper part, while at the southern point the rock is more siliceous.

In the excavations about the Golspie Bridge, and in digging the foundations of the Golspie Inn, the same rock was met with (*Farey*).

In the bank south-west of Dunrobin Castle, in what is known as the Quarry Park, there is an old pit where the rock was formerly dug for lime-burning and for marl, and where its characters can be still examined. Here, as in Dunrobin Glen, we find the most complete agreement between this rock and the well-marked Cherty Rock of Stotfield.

Lastly, the rock can be traced running out to sea in the reefs between Dunrobin and Golspie. Here the calcareous portions are dissolved away, and the cavernous masses of cherty material are seen, identical in every respect with the similar weathered masses of Stotfield shore and Spynie Hill.

These last hard masses of chert have been the means of preserving the sandstones below from destruction by denudation, in the same manner as we have seen to be the case in Elginshire. The thickness of sandstone exposed is not great, probably not more than 40 or 50 feet; but the similarity of the rock in colour, texture, and mode of weathering to the Reptiliferous Sandstone is most striking. It is true that these sandstones have not yielded any reptilian remains, or, indeed, any kind of fossils; but it must be remembered that the sandstones of Elginshire are equally barren to much greater depths, all the fossils having been obtained from one bed, which is at a lower horizon than any part of the series exposed in Sutherland. The fucus-covered and rarely accessible reefs of the latter county also afford no such facilities for the detection of fossils as are presented by the extensive quarries of Elginshire. The Dunrobin reefs can only be seen at low water; and, indeed, it is only during spring tides that a satisfactory examination can be made of the lowest of them.

It is, I believe, impossible for any one to examine these rocks on the north and south side of the Moray Firth respectively, especially bearing in mind the *unique* features presented by the higher and calcareous beds, without being fully convinced of their complete identity.

The relations of these strata are, as already intimated, perfectly clear in the county of Sutherland, and they are such as to con-

Fig. 14.—*Section exposed in the reefs below Dunrobin Castle.*

x, x. Shingle.
a. "Reptiliferous Sandstones." } Trias.
b. "Cherty Rock of Stotfield." }
c. Sandstones and conglomerates with pebbles derived from *a* and *b* (Rhætic?)
d. Estuarine series—sandstones, shales, and coals, plant-remains, &c. (Lias *α*?).
e. Alternations of clays and shelly limestones; marine fossils (Lias *β*).
f. Blue micaceous clays; marine fossils (Lias *γ*).

clusively establish, as I believe, the Secondary age of the long-disputed beds (fig. 14).

The beds referred to are seen at Dunrobin to underlie *conformably* a considerable thickness of strata, which I shall demonstrate by most abundant palæontological evidence to be of the age of the Middle and Lower Lias. With these Mesozoic strata the formation in question agrees both in strike and dip, while with the Old Red Sandstone strata, which are exhibited in close proximity, it has no common relations whatever. Indeed, the strata in question appear to have been seen by Sir R. I. Murchison, though probably not under favourable conditions, and were by him unhesitatingly placed in the Secondary series.

There are two objections which may possibly be urged against the view which I have taken of the relations of this formation in Sutherland.

It may be said that the agreement in strike and dip of the strata at Dunrobin may be accidental, and that the Lias strata, instead of overlying the calcareous and cherty rock, may be faulted against it. This objection may appear to receive some support from the facts which I have already pointed out, indicating the greatly faulted condition of these Sutherland rocks.

To this objection there is fortunately the most complete answer. The lowest beds of the Lias series, as is so often the case, consist of a conglomerate; and among the pebbles in these beds are numerous fragments of the peculiar calcareous and cherty rock so frequently referred to.

It may also be urged that possibly the conformity of the beds of the formation in question with the overlying Lias strata may be *accidental*, and that in spite of it they may be of as early date as the Old Red Sandstone.

In reply to this objection I would point to the fact that in Golspie Burn the Cherty Rock of Stotfield is seen at only a very short distance from beds of undoubted Old Red Sandstone strata, and that while the latter are greatly disturbed and dip S.E., at an angle of 70°, the former dips N.N.E. 12°, conformably to the great mass of Secondary strata here.

The facts now adduced with regard to the stratigraphical relations of the "Cherty Rock of Stotfield" and the underlying sandstone (which we cannot hesitate to recognize as the

Reptiliferous Sandstone) in the county of Sutherland are such as to prove that these strata are of Secondary age, and that they are older than the Lower Lias.

I have argued this question hitherto mainly on stratigraphical grounds, and have shown that there would be the strongest reasons for believing the formation in question to be of Secondary age, even if there were a total absence of all palæontological evidence.

But this is very far from being the case. The interesting descriptions of *Stagonolepis*, *Telerpeton*, and *Hyperodapedon* by Professor Huxley, and his discussion of their bearing on the age of the Reptiliferous Sandstones of Elgin are too fresh in the minds of all geologists to need recapitulation here. In 1858 Professor Huxley declared* that the palæontological evidence in favour of the Secondary age of the reptiles was so weighty as to "lead one to require the strongest stratigraphical proof before admitting the palæozoic age of the beds in which they occur." Since that date he has, as every one is aware, greatly strengthened that palæontological evidence by demonstrating that, alike in Warwickshire, Devonshire, and India, *Hyperodapedon* occurs in beds of Triassic age†.

Thus we find that the stratigraphical and the palæontological evidence with regard to this interesting formation in the north-east of Scotland are in complete accord, and we are justified in regarding it as of undoubted Triassic age—a fact which is of the greater interest from the circumstance that strata of that period are of such rare occurrence in Scotland.

Sir Roderick Murchison has suggested that, if the Reptiliferous Sandstones are to be referred to the Trias, they must in all probability be considered as representing the Keuper sandstones‡. In that case it may be consistent to place the "Cherty Rock of Stotfield" on the horizon of the lower part of the New Red marls. The partial break indicated by the overlying conglomerate beds, unattended as it is by any difference of dip, would be perfectly consistent with the absence of the higher portions of the Keuper series.

It was also pointed out by Sir Roderick§ that there might be in Elginshire and Ross-shire an *accidental* conformity between beds differing as greatly in age as the Trias and Upper Old Red, and that on this supposition the apparent anomalies presented by the district might be accounted for. From a careful examination, however, of the whole question of the relations of the Primary and Secondary rocks around the Moray Firth, I am led to infer that the true key to the enigma presented by the Elginshire rocks is to be found in the great faults which certainly traverse the whole of the district, and as certainly have been the cause of even more striking phenomena in other parts of it.

There are good reasons for believing that these Triassic strata of the north-east of Scotland are, like those of England (as has been

* Quart. Journ. Geol. Soc. vol. xv. (1859) p. 460.
† Ibid. vol. xxv. (1869) p. 138.
‡ Siluria, 5th edit. (1867) pp. 267, 268.
§ Ibid.

argued by Professor Ramsay, Mr. Godwin-Austen and others), of lacustrine origin,—a conclusion supported by the paucity of organic remains in them, and the peculiar characters of the rock which forms their upper member.

§ 2. *The Rhætic?*

At the base of the Liassic series of strata in Sutherland, and immediately overlying the formation just described, there occurs a series of coarse sandstones with beds of conglomerate (fig. 14, *c*, page 143). As has been already pointed out, the pebbles in this conglomerate are not derived from the Old Red Sandstone or any other Palæozoic rock, but in part at least, from the sandstones and cherty limestones of the Trias. The base of the Lias in Scotland, as in South Wales and many parts of France and Germany, is usually formed by similar conglomerates; but on the Western Coast the Secondary rocks generally repose unconformably on the older Palæozoic strata, such as the Silurian and Cambrian, and the conglomerates are made up of pebbles of those rocks.

These conglomerates and sandstones of Sutherland, which attain a considerable thickness, but are somewhat imperfectly exposed, have not exhibited any trace of those bone-beds sometimes found in equivalent strata; nor, indeed, have they yielded any kind of fossil remains whatever. As indicating the slight oscillations of level, insufficient to produce unconformity, which marked the gradual transition from the Trias to the Lias, we may, with a strong show of probability, consider them to be of Rhætic age. They are evidently a littoral deposit, and are overlain by, and graduate up into the series of estuarine strata constituting the base of the Lower Lias.

On the opposite or southern side of the Moray Firth there are a number of masses of strata, not *in situ*, but included in the Boulder-clay, which from their mineral characters have been variously referred by different authors to the Wealden, Purbeck, and Rhætic. I have already pointed out how little weight should be attached to mere mineral characters in the determination of the age of the Secondary strata of Scotland; and as the masses in question are completely isolated in the drift, we are reduced to the purely palæontological evidence.

The most important of these masses is that of Linksfield, which was first brought under the notice of geologists by Dr. Gordon in 1832*. The peculiarities of the strata here were found by Dr. Malcolmson to be such as to lead him, in the year 1838†, to suggest that they were the equivalents of the Wealden or Purbeck—a view that was adopted by Mr. Duff, Mr. Robertson and other observers‡. On the other hand, Mr. C. Moore§, in the year 1859, pointed out the striking resemblances in the mineral characters and succession of

* Proc. Geol. Soc. vol. i. p. 394. † Ibid. vol. ii. p. 667.

‡ Sketch of the Geology of Moray, 1842; Anderson's 'Guide to the Highlands,' 3rd edition (1851); &c.

§ Brit. Assoc. Rept. (1859) p. 264. Quart. Journ. Geol. Soc. vol. xvi (1860) p. 445.

the beds at Linksfield to those of the Rhætic formation in the south-west of England, and he showed that there exists some palæontological evidence in favour of identifying the two series. In this view he was confirmed by Professor Rupert Jones*.

The remarkable position of the mass of Secondary strata at Linksfield has given rise to a number of hypotheses to account for it. The chief of these are as follows:—

(1) That the stratified clays and limestones once rested immediately upon the Triassic limestone, and that the foot of a glacier or iceberg forced the two sets of strata asunder, carrying with it a mass of glacial detritus and scoring and polishing the hard surface of the lower rock. This hypothesis appears to have been first suggested by Mr. A. Robertson, of Inverugie, and Captain Brickenden†, and to have received the sanction of Professor Agassiz.

(2) The hypothesis suggested by Sir Charles Lyell at the Aberdeen Meeting of the British Association (1859) is as follows:—"That a range of cliffs, of Triassic and Lower Liassic beds, rose above the Vale of Elgin during the glacial epoch, when ice rafts and drifting bergs, with all the phenomena of an Arctic sea, swept down that vale, then a frith, and that the siliceous cornstone was then the actual sea-bed. The icebergs and drifting masses undermined the soft marls of the Upper Trias and Lias, and in time produced a landslip. The whole side of a sea-cliff slipped down from its position, on to a beach of Boulder-clay, without any bouleversement of the strata"‡.

(3) The view first put forward by Dr. Gordon§ and other local observers, and since advocated by Professors Geikie and Ramsay‖, is, that the mass of Linksfield and similar masses in the neighbourhood are really great transported blocks, which have been carried by ice across the sea in which the Boulder-clay was formed, and quietly deposited at the bottom by the stranding and gradual melting of the ice rafts.

The results of the more careful and exact studies of the modes of ice-action made during recent years have been such as, I believe, to lend but little support to the first of these hypotheses, while on the contrary they have, by furnishing undoubted examples of analogous action and by showing the futility of supposed objections, removed many of the difficulties which prevented the acceptance of either of the two other hypotheses.

The preservation of a mass of strata, higher in the series than the

* Monograph of the Fossil Estheriæ (Palæontographical Society, 1862), pp. 74–77.

† Quart. Journ. Geol. Soc. vol. vii. (1851) p. 291 See also A. Robertson, in Anderson's 'Guide to the Highlands,' 3rd ed. (1851) p. 344; a similar view appears to have been hinted at by Mr. Duff, 'Sketch of the Geology of Moray' (1842).

‡ Symonds in Edin. New Phil. Journ. New Ser. vol. xii. (1860) p. 100, and Quart. Journ. Geol. Soc. vol. xvi. (1860) p. 459.

§ Edin. New Phil. Journ. New Ser. vol. ix. (1859) p. 52. Ibid. vol. iv. (1856) p. 223.

‖ Quart. Journ. Geol. Soc. vol. xxvii. (1871) p. 252.

beds in the immediate neighbourhood, through being let down by faults, is a phenomenon familiar to every geologist, and, indeed, is illustrated by wonderful examples cited in the present memoir. That landslips acting during the Glacial epoch might have produced a similar result on a small scale is clear; and, indeed, examples of the kind have presented themselves to me during my survey of districts thickly covered with drift in the Midland counties of England *. I have already shown reasons for believing that the Secondary strata were largely developed in the Elgin district.

On the other hand, the principal objection which has been raised to the hypothesis that the Linksfield mass is a boulder †, namely that of its great size, has been effectually disposed of by the discovery of undoubted transported masses of equal, and even greater dimensions, imbedded in the Boulder-clay of other districts ‡.

It is not my purpose to attempt to decide between these two hypotheses, both of which appear to harmonize equally well with all the phenomena of the case—the glacially striated and polished rock at the bottom of the section, the overlying and underlying Boulder-clay, containing detached fragments of the same beds, and sometimes filling fissures in the principal mass, and the contorted, cracked, and sometimes dislocated appearances presented by the latter. The two hypotheses have some points in common; for it is evident that in order to account for the transportation of such enormous masses by means of *ice rafts*, we must suppose that they have been deposited on the surface of the ice-foot by means of *landslips*. Perhaps it will be more logical in all such cases to avoid calling in the agency of these vast ice-floats except in the cases (of which there are many) in which it can be clearly shown not only that the rocks composing the masses are absent in the neighbourhood *now*, but that it is impossible that they could have existed in the vicinity as escarpments during the Glacial period.

The section at Linksfield is now unfortunately closed, the quarrying of the limestone below the shales and Boulder-clay having been abandoned. Admirably detailed descriptions of the succession of the beds, however, have been published by Malcolmson §, Duff ||, Brickenden ¶, and Moore **.

Although the Linksfield beds are highly fossiliferous, there is considerable difficulty in fixing their exact age. The fallacy of the arguments derived from the mineral characters and the succession of the beds, on the strength of which they have been successively

* These and many examples of transported masses of enormous dimensions will be described in a forthcoming memoir of the Geological Survey.

† Symonds, Edin. New Phil. Journ. New Ser. vol. xii (1860) p. 100.

‡ See Morris, Quart. Journ. Geol. Soc. vol. ix. (1853) p. 317; Ramsay, ibid. xxvii. (1871) p. 252; also Fisher, Geological Magazine, vol. v. (1868) p. 407; and Bonney, ibid. vol. ix. (1872) p. 403.

§ Proc. Geol. Soc. vol. ii. p. 667; and Edin. New Phil. Journ. New Ser. vol. ix. (1859) p. 48.

|| Sketch of the Geology of Moray, p. 15, plate iii.

¶ Quart. Journ. Geol. Soc. vol. vii. (1851) p. 291.

** Ibid. vol. xvi. (1860) p. 446.

referred to the Wealden, the Purbeck, and the Rhætic, has been already pointed out. The finely laminated variegated clays, the beds of fibrous carbonate of lime ("beef" and "bacon" of the Purbeck quarrymen), the *bone-bed* and numerous scattered fish-remains, the admixture of dwarfed marine with fresh- or brackish-water species, the bands crowded with *Cyprides,* and the abundance of *Estheriæ,* all appear to indicate the prevalence, as in the formations referred to, of *estuarine conditions*; but they afford us no criteria for determining the *age* of the beds. Strata of almost identical mineral characters occur in Sutherland at the base of the Middle Oolites; but I do not find any such community of species between the two sets of strata as would justify their identification. The following is the list of the species which have been obtained from the Linksfield beds.

List of Fossils from the Linksfield Shales.

Femur of a species of Trionyx (determined by Professor Owen).
Vertebræ of Plesiosaurus, sp.
Scales of Semiotus punctatus, *A. Robertson,* M.S.
—— Lepidotus minor, *Ag.*
—— Pholidophorus, sp.
—— Eugnathus, sp.
Teeth of Hybodus Lawsoni, *Duff.*
—— —— dubius, *Ag.*
—— Sphenonchus Martini, *Ag.*
Acrodus, sp.
Spines of Hybodus.
Ostrea, sp.
Pteroperna, sp.
Mytilus, sp.
Modiola Hillana, *Sow.*
——, sp.
Astarte, sp.
Unio, sp.
Cyrena.
Cyclas (several species).
Melanopsis, sp.
Paludina, sp.
Planorbis, sp.
Candona? globosa, *Duff,* sp.
Estheria minuta, *Alberti,* var. Brodieana, *Rupert Jones.*
Spine of Echinoderm.
Neuropteris and other ferns.
Fragments of wood.

Several of the species of marine mollusks which occur at Linksfield appear to be undistinguishable from forms described by Professor Hébert from the Rhætic of Högonäs, in Scania. But the evidently dwarfed and abnormal condition of the fossils in both places is such as to deter me from making any positive identification.

The species of fishes described by Agassiz appear to be nearly all peculiar to this locality; but the general association of the genera, though consistent either with the hypothesis of the Liassic or of the Oolitic age of the beds, seems to be rather in favour of the former. The marine mollusca are all evidently dwarfed, and the determination of their species thus rendered difficult and doubtful; Mr. C. Moore, however, has identified *Modiola Hillana,* Sow., a Lower Lias form. The species of *Cypris* affords us no assistance; but the *Estheria,* though belonging to a species having a very extended range, is referred by Professor Rupert Jones to a variety which has hitherto been obtained only from the Rhætic; yet it is at the same time shown to present some differences from the specimens undoubtedly of that age. It will thus be seen that the palæontological evidence concerning the age of the Linksfield beds is far from being strong or conclusive; but the balance of it is certainly in favour of our considering the strata of Rhætic or Lower-Lias age.

It is possible that, during the "infra-Liassic" period, beds of conglomerate like those of the Dunrobin reefs may have been formed at one point while strata like those of Linksfield were deposited at no great distance. In fact we have a perfectly similar example in the south-west of England in the "Lias-conglomerate" of South Wales and the Rhætic Shales of the Bristol Channel. On the other hand it is very probable that associated with the beds of Lower-Lias age which contain coal-beds and are so imperfectly exposed at Dunrobin, the exact counterpart of the Linksfield shales may exist. At the same time, the presence of beds in this district formed under similar estuarine conditions at various horizons during the Jurassic period will justify us in hesitating to fix absolutely the age of the isolated strata of Linksfield, in the absence of more precise palæontological evidence.

A number of fragmentary masses of strata similar to that of Linksfield have been found at several places in the neighbourhood—namely, at Maryhill, Pitgaveny, Spynie Hill, and Waukmill.

The close resemblance between the fossils of the strata at Linksfield and those so admirably described by M. Hébert in very similar beds at Högonäs, in Sweden, if it does not warrant the absolute identification of the two series, affords strong grounds for the suspicion that they are on nearly the same geological horizon.

§ 3. *The Lower Lias.*

The conglomerates and sandstones on the shore at Dunrobin, which we have shown reasons for regarding as of Rhætic age, are covered conformably by, and, indeed, appear to graduate into, an interesting series of estuarine strata, composed of sandstones, shales, and beds of coal, and attaining a very considerable thickness, which I estimate from the angle of dip and breadth of outcrop to be not less than from 400 to 500 feet (see fig. 14, *d*, page 143). Unfortunately these strata are very imperfectly exposed; for under ordinary circumstances only the harder beds appear as reefs upon the shore; when, however, the beach is temporarily scoured away by heavy storms, the bassets of the softer strata of clay and coal are sometimes exposed. It was thus that a bed of coal was exposed to the E.N.E. of Dunrobin Pier, which led in the year 1770 to a boring being undertaken in the Summer-house Park adjoining. The only record of this boring which remains states that "two thin seams of coal were proved, but not deemed worth working."

The sandstones of this series appear to present the usual characteristics of the arenaceous type of the Jurassic estuarine beds. They sometimes contain numerous laminæ of carbonaceous matter, and at others are crowded with vertical plant-markings, like the so-called "root-beds" of the Midland district of England. In one of the highest of these beds of sandstone I detected casts of *Pecten* and other marine shells, indicating that there is a gradual passage from these estuarine strata to the marine beds overlying them. The carbonaceous seams associated with the series appear to be well-

formed coals, and not lignites, but they contain much pyrites. The argillaceous strata I have never found sufficiently well exposed to enable me to make an adequate examination of them.

Lithology.	Thickness.	Fossils.
(*Clays of the Middle Lias.*)		
(1.) Bed of coarse blue sandstone, in places highly micaceous, with a few pebbles of quartz scattered through it. The top of this bed is highly pyritous; and the bottom passes into a grit.	1 ft. 6 in.	Fossils rare:— *Belemnites acutus*, Mill. *Pecten sublævis*, Phil. *Pecten liasinus*, Nyst.
(2.) Beds of very sandy micaceous blue clay, with a few irregular and inconstant bands of sandstone.	3 ft.	*Gryphæa obliqua*, Sow. (dwarfed form), very abundant. *Pleuromya, Pecten.* Casts of other bivalves.
(3.) Alternations of very hard laminated fine-grained micaceous sandstone and shaly micaceous sandy blue-clay.	3 ft.	Few fossils.
(4.) Thick mass of finely laminated sandy and highly micaceous blue-clay, the joints of which are filled with sandstone.	8 ft.	A few scattered Oysters. *Pleuromya unioides*, Röm., sp. Carbonaceous markings.
(5.) Soft, somewhat micaceous, laminated sandstone of a greenish colour (graduating downwards into 6).	3 ft.	A few carbonaceous markings.
(6.) Thick bed of blue micaceous clay, with irregular bands of sandstone. In its lower part this bed becomes less sandy, and contains some septaria.	About 15 ft.	Carbonaceous markings abundant. A few fossils scattered through it:—*Rhynchonella variabilis*, Schloth., var.; *Lima pectinoides*, Sow.; *Gryphæa obliqua*, Sow. (dwarfed form); *Cardinia hybrida*, rare; *Pleuromya unioides*, Röm., sp., rare; *Belemnites acutus*, Mill.; crushed bivalves.
(7.) Alternations of clays and limestones crowded with Oysters and *Cardiniæ*, and other shells. There are two principal beds of limestone; and these occasionally contain quartz pebbles scattered through them.	16 ft.	Fossils very abundant:—*Ammonites* and *Belemnites*; *Gryphæa obliqua*, Sow.; *Cardinia hybrida*, Sow., sp.; *Lima pectinoides*, Sow., sp., &c. &c. (see list).
(8.) Bed of greenish very micaceous sandstone.	2 ft.	Few fossils. Cast of *Pecten*. Full of Fucoid (?) markings.
(9.) Finely laminated, highly micaceous, dark blue-clays.	10 ft.	Crushed shells (*Cardinia* and *Pecten*). Wood.
(10.) Soft greyish blue sandstone.	9 in.	Oysters and other shells (fragmentary).
(11.) Blue clay.	Bottom not seen, about 20 ft.	*Cardinia hybrida*, Sow., sp. *Gryphæa obliqua*, Sow. (dwarfed form). Crushed bivalves.
(*Estuarine sandstones, coals, &c.*)		

At the top of this series of estuarine strata we find a formation, consisting of alternations of blue micaceous clays and hard impure

shelly limestones, and containing very numerous marine fossils (see fig. 14, *e*, page 143). Although these strata are unquestionably marine, yet the nature of the beds, the assemblage of genera in their fauna, the dwarfed condition of the Oysters and some other forms, and the abundance of fragments of carbonaceous matter lead us to regard them as formed under comparatively shallow-water conditions; and, as we have already seen, they graduate into the estuarine strata below. These beds are tolerably well exposed in a number of reefs on the shore, a little to the north-east of Dunrobin Castle, which reefs have a nearly E. and W. strike, and a northerly dip of from 12° to 15°. The nature, order of succession, and palæontological features of these strata are shown in the Table (p. 150), the thicknesses being partly measured, and partly estimated.

The species of fossils derived from these beds, which I have been able to accurately determine, are as follows, the majority being obtained from the division marked (7):—

Fossils of the Lower Lias Limestones and Shales. Dunrobin Reefs.

Belemnites acutus, *Mill.* (abundant, but small).
Ammonites caprotinus, *D'Orb.* (abundant, but badly preserved).
——, sp. (rare).
—— oxynotus, *Quenst.* (tolerably abundant).
—— ——, var. (rare).
Panopæa, sp.
Pholadomya ambigua, *Sow.*, var.
——, sp.
Pleuromya unioides, *Röm.*, sp.
Tancredia?, sp.
Hippopodium, sp.
Cardinia lanceolata, *Stutch.*, sp. (not rare).
—— ——, var.
—— hybrida, *Sow.*, sp. (very abundant).
Unicardium cardioides, *Phil.*, sp.
Modiola, spec. nov.
Mytilus (Modiola) numismalis, *Oppel.*
Pecten, sp.
—— liasinus, *Nyst.*
—— tumidus, *Ziet.*
—— textorius, *Schloth.*
—— sublævis, *Phil.*
Pinna Hartmanni, *Ziet.*
Lima Koninckana?, *Chap. et Dew.* (rare).
—— punctata, *Sow.* (rare).
—— pectinoides, *Sow.*, sp. (very abundant).
Ostrea?, sp.
Gryphæa obliqua, *Sow.* (rare).
—— ——, *Sow.* Dwarfed variety of Quenstedt (very abundant).
Rhynchonella tetrahedra, *Sow.* (abundant).
—— variabilis, *Schloth.*, var. triplicata, *Phil.*
Wood, &c.

The series of estuarine and associated marine strata which we have been describing was noticed by Sir Roderick Murchison in his earliest memoir. Unfortunately the fossils then collected by him were few in number, and the determination made of them not of a

sufficiently exact character for fixing the age of the beds; but from the resemblance in petrological characters of the strata exposed at Dunrobin to those near Brora, he was led to regard the former as a mere repetition of the latter, and therefore of Lower-Oolite age. In later years Sir Roderick Murchison obtained specimens of *Hippopodium ponderosum*, Sow., from the Dunrobin shore, and was thus led to the recognition of the fact that strata of Liassic age exist there*.

The two patches of strata which were in 1826 referred to the Lias by the same author as the result of a confessedly somewhat hasty examination†, and which have since been almost uniformly so regarded by geologists in Scotland, will be shown in this memoir to be of the age of the Coralline Oolite and the Kimmeridge Clay respectively.

With regard to the marine strata, which form the upper part of the series we have been describing as occurring at Dunrobin, there is fortunately no room for doubt as to the question of their position in the geological scale. An inspection of the list of fossils will show that the beds which yield them undoubtedly belong to the Lower Lias, and to that part of it which Quenstedt has distinguished as the Lias β. This is the highest portion of the Lower Lias according to the classification usually adopted on the Continent, but its middle portion according to the English method of grouping the beds.

The fauna of these beds at Dunrobin is not without some anomalous characters, some of which, such as the rarity and small size of the Cephalopoda, the dwarfed condition of the Oysters, and the absence of Echinoderms and of many of the species of Mollusca usually found at this horizon, may be accounted for on the ground that the beds were probably deposited under less favourable conditions than their typical equivalents in England and Swabia. These unfavourable conditions would appear to have been the shallower and less tranquil state of the sea, and possibly also the colder climate. Certain other of the peculiarities, as for example the association in the same bed of species which in Swabia characterize distinct but contiguous horizons, must be referred to the fact that the beds were deposited in a remote locality, and that the character of the fauna would thus be influenced by the varying migrations of some, and the unequal persistence and gradual extinction of other species. Nevertheless, in spite of these minor peculiarities, no one acquainted with the association of Jurassic species in England, Northern France, and Western Germany, can hesitate to regard these beds in the north of Scotland as the deposits of a portion of the same great sea, and as included within the same ancient province of marine life.

Having thus, by means of the beautiful marine fauna of its higher beds, fixed the newer limit of age of the series of estuarine beds at Dunrobin, the base of which is formed by deposits certainly Triassic, and others probably Rhætic, we can have little hesitation in regard-

* See First Sketch of a Geological Map of Scotland, 1861; also Quart. Journ. Geol. Soc. vol. xv. (1859) plate xii.

† Trans. Geol. Soc. 2nd ser. vol. ii. part 2, p. 307.

ing these same estuarine strata as representing the lower part of the Lias β and the whole of the Lias α of Quenstedt. That marine representatives of these strata were wanting on the east coast of Scotland appears to be proved by the following fact. It will be shown that of almost every portion of the series of Jurassic strata seen in Sutherland, fragments, often very numerous and sometimes of enormous size, are found in the drifts of the east coast of Scotland; but among the numerous series of fossils collected from these same drifts I have never yet detected a single example of the usually remarkably abundant *Gryphæa arcuata*, Lam. (*G. incurva*, Sow.), nor of any of its associated forms. Marine strata of this age, however, are, as will be shown hereafter, remarkably well developed on the western coasts of Scotland.

Of the marine strata forming the upper part of the Lower Lias very numerous fragments occur in the drifts of the east of Scotland. Mr. A. Robertson collected at Inverugie a large series of fossils from fragments of shelly limestone of this age; and I found at Kaim, to the north-west of Elgin, numerous large boulders derived from the same source. These transported fragments appear to indicate that in the east of Scotland there once existed beds of limestone of this age, thicker and better-defined than those in the patch which has escaped destruction at Dunrobin. The following fossils have been collected at Kaim and Inverugie:—

Fossils from transported blocks of Lower Lias (micaceous sandy limestone) at Kaim, Elginshire.

Ammonites caprotinus, *D'Orb.*
Cardinia hybrida, *Sow.*, sp.
—— crassiuscula, *Sow.*, sp.
——, sp.
Hippopodium, sp.?
Cypricardia, sp.
Unicardium cardioides, *Phil.*, sp.
Pecten textorius, *Schloth.*
—— tumidus, *Ziet.*
—— liasinus, *Nyst.*
Ostrea semiplicata, *Münst.*
Gryphæa obliqua, *Sow.*, var.
Rhynchonella variabilis, *Schloth.*

Fossils from boulders of Lower Lias (same rock as last) at Inverugie, Elginshire.

Ammonites oxynotus, *Quenst.*
—— caprotinus, *D'Orb.*
—— Masseanus?, *D'Orb.*
Pleurotomaria, sp.
Natica, sp.
Panopæa, sp.
Pleuromya unioides, *Röm.*, sp.
Anatina?, sp.
Pholadomya ambigua, *Sow.*, var.
Ceromya?, sp.
Cardinia hybrida, *Sow.*, sp.
—— crassiuscula, *Sow.*, sp.
——, sp.
Hippopodium, sp.
Unicardium cardioides, *Phil.*, sp.
Cypricardia, sp.
Astarte, sp.
Myoconcha psilonoti?, *Quenst.*
Modiola scalprum, *Sow.*
—— Hillana, *Sow.*
Mytilus, sp.
Lima pectinoides, *Sow.*, sp.
—— punctata, *Sow.*, sp.
Pinna Hartmanni, *Ziet.*
Avicula sinemuriensis, *D'Orb.*
—— (Monotis) papyrea, *Quenst.*
Pteroperna (Gervillia) betacalcis, *Quenst.*
Plicatula spinosa, *Sow.*
Pecten textorius, *Schloth.*
—— liasinus, *Nyst.*
—— tumidus, *Ziet.*
——, sp.
Gryphæa obliqua, *Sow.*, var.
Ostrea semiplicata, *Münst.*

In Scania, in the neighbourhood of Helsingborg, &c., the strata of Rhætic age, which we have referred to as existing at Högonäs are covered by a great series of beds of sandstone, micaceous shales, impure lignites, and coals. These are said to attain, in places, a thickness of 1000 feet. In the Prince-Charles Mines a pit has been sunk to the depth of 280 feet, which passed through five beds of coal, the first four being only from 4 to 6 inches thick; but the lowest, which, however, contains some intercalated seams of clay, is upwards of 4 feet thick. The sandstones of Hör, too, which have yielded a very interesting flora, are shown also to belong to the base of the Lower Lias. This agreement in characters between the strata of the same age in Scotland and Scandinavia, of which only such isolated fragments now remain, is a point of great interest and suggestiveness.

§ 4. *The Middle Lias.*

Reposing on the fossiliferous clays and limestones at Dunrobin, which we have just described, we find a considerable thickness of dark blue, very finely laminated and highly micaceous clays, containing a few thread-like concretions of pyrites, and very numerous, small, and curiously shaped nodules of argillaceous limestone (see fig. 14, *f*, page 143). At some distance from the base very large septaria occur, and still higher a few irregular indurated bands containing Oysters and *Hippopodium ponderosum*, Sow.

The total thickness of clays seen here is about 80 feet, as estimated from the dip and breadth of outcrop. To the north the shore is altogether covered by great boulders. There is good reason, however, for believing that a great transverse fault occurs near here, which brings the clays of the Middle Oolite, which are seen in the brickyard and trial-pits at Clayside, against the clays of the Middle Lias. The clay-beds, on the shore at Dunrobin, have yielded a considerable number of fossils, sufficient, indeed, to place their age beyond question; these are recorded in the following list:—

Fossils of the Middle-Lias Clays, Dunrobin Reefs.

Belemnites acutus, *Mill.* (abundant, but generally very small).
—— clavatus, *Schloth.*
Ammonites brevispina, *Sow.* (not rare).
—— ——, var.
—— Jamesoni, *Sow.*, var. (rare).
—— oxynotus, *Quenst.*, var. (very rare).
Helicina expansa?, *Sow.*, sp.
Turbo canalis, *Goldf.*
Pholadomya decorata, *Goldf.*
Pleuromya unioides, *Röm.*, sp.
Cardinia lanceolata, *Stutch.*, sp.
—— attenuata, *Sow.* (rare).
Hippopodium ponderosum, *Sow.*, large rugose variety (very abundant).
Cardium truncatum?, *Sow.*
Unicardium cardioides, *Phil.*, sp.
Cucullæa Münsteri, *Goldf.*
Arca Buckmanni, *Rich.*
Mytilus (Modiola) numismalis, *Oppel.*
Limea acuticosta, *Goldf.*
Lima pectinoides, *Sow.*, sp. (rare).
——, sp.
Pinna folium, *Y. & B.*
Pecten liasinus, *Nyst.*
—— sublævis, *Phil.*
—— priscus, *Schloth.*
Plicatula spinosa, *Sow.*
—— lævigata?, *D'Orb.*
Gryphæa cymbium, *Lam.* (G. Maccullochii, *Sow.*).
—— obliqua, *Sow.*, var.
Terebratula punctata, *Sow.*
Rhynchonella amalthei, *Quenst.*
Pentacrinus moniliferus, *Quenst.* (rare).
Wood in form of jet.

The geological horizon indicated by this fauna is not less clear than that of the beds below. The age of the thick beds of blue clay at Dunrobin is, without doubt, that of Quenstedt's Lias γ (that is, the lower part of the Middle Lias of continental geologists, the higher part of the Lower Lias according to our English classification). These beds were probably deposited in deeper and more tranquil water than were those below them, the conditions indicated being not very dissimilar to those which must have prevailed during the deposition of the equivalent strata in England. The peculiarities of their fauna, therefore, such as the persistence of *Ammonites oxynotus*, Quenst. (though in a dwarfed condition), and of *Belemnites acutus*, Mill., both of which species become extinct in the typical localities before the close of the Lias β period, as well as the rarity of the Ammonites, especially those of the group of the *Armati*, usually very characteristic of the zone, can only be ascribed to difference of climate or to their geographical position, so remote from the sections which have served as standards of our Liassic classification.

Although no higher beds in the Middle Lias series are exhibited in Sutherland, owing to the fault referred to, we are fortunately not left altogether in doubt as to the characters assumed by the strata of that age in the east of Scotland. Among the boulders in Elginshire and the adjoining counties, none are more common than masses composed of a fine-grained micaceous sandstone, of a light colour, crowded with fossils which prove them to belong to the horizon immediately above that of the clay just described. Among the localities which have yielded such boulders I may mention especially the Loch of Spynie, Lhanbryd, Ashgrove near Elgin, Urquhart, several spots near Banff, &c.

When I have described the Middle Lias strata of the western coast of Scotland, their similarity to those just described in the micaceous sandstones above and the blue shales below, will be made apparent. It will be seen that during the periods represented by portions of the Middle Lias and the Middle Oolite, more uniform and comparatively deep-water marine conditions prevailed in Scotland. The full consideration of this and similar questions, however, I reserve for the third part of this memoir.

At two localities, namely Lhanbryd and Loch Spynie, the fragments of the Middle Lias sandstone have been found in such abundance as to lead to the impression that the rock is *in situ* at or near the place. A careful examination of the question, however, shows that the masses of rock are certainly enclosed in the Boulder-clay. The accumulation of portions of the same bed at certain points may be accounted for, as already hinted, by regarding them as brought by an iceberg which had received its freight of detritus at some locality where the parent rock was developed. The species of fossils from these two localities are so numerous, interesting, and well preserved, that I am induced to give lists of them. Those from Loch Spynie are nearly all from the cabinet of that indefatigable collector, Mr. Grant, of Lossiemouth.

List of Fossils from boulders of Middle Lias (micaceous calcareous sandstone), Loch Spynie, Morayshire.

Glyphea rostrata, *Phil.*, sp.
Belemnites paxillosus, *Schloth.*
Ammonites Jamesoni? *Sow.*, var.
Helicina expansa, *Sow.*, sp.
Chemnitzia undulata, *D'Orb.*, sp.
Turritella, sp.
Turbo, sp.
Trochus, sp.
Pleurotomaria, sp.
Cylindrites, sp.
Pholadomya ambigua, *Sow.*, var.
Myacites, sp.
Pleuromya unioides, *Röm.*, sp.
Panopæa elongata, *Röm.*
Isocardia?
Goniomya, sp.
Arca Buckmanni, *Rich.*
Myoconcha scabra, *Terq.* et *Piette.*
Cypricardia, sp.
Unicardium cardioides, *Phil.*, sp.
Cardium truncatum, *Sow.*
Cardinia, sp. (rare).
Modiola scalprum, *Sow.*
Lima, sp.
Pinna folium, *Y. & B.*
Pecten liasinus, *Nyst.*
—— sublævis, *Phil.*
—— disparilis, *Quenst.*
Plicatula spinosa, *Sow.*
—— lævigata?, *D'Orb.*
Placunopsis, sp.
Gryphæa obliqua, *Sow.*
Serpula, sp.

List of Fossils from the boulders of Middle-Lias rocks found at Lhanbryd, Elginshire.

Belemnites paxillosus, *Schloth.*
Ammonites Actæon, *D'Orb.*
—— oxynotus?, *Quenst.*
——, sp.
Helicina expansa, *Sow.*, sp.
Pleuromya unioides, *Röm.*
Myacites, sp.
Panopæa elongata, *Röm.*
Cardinia philea, *D'Orb.*
Hippopodium, sp.
Unicardium cardioides, *Phil.*, sp.
Cardium truncatum, *Sow.*
Isocardia? sp.
Tancredia, sp.
Cucullæa, sp.
Lima pectinoides, *Sow.*
—— punctata, *Sow.*
Avicula inæquivalvis, *Sow.*
Crenatula ventricosa, *Sow.*
Pinna folium, *Y. & B.*
Hinnites (near abjectus, *Phil.*).
Pecten disparilis, *Quenst.*
—— sublævis, *Phil.*
—— liasinus, *Nyst.*
Gryphæa obliqua, *Sow.* (dwarfed form).
Ophioderma Egertoni, *Brodie.*
Dicotyledonous wood.

Although, as already noticed, these fossils are certainly derived from transported masses (the only rock of Jurassic age certainly *in situ* on the south side of the Moray Firth being that already described as occurring at Stotfield), yet it must be remembered that over very large areas the rocks are totally concealed by drifts; and, as we have seen that they are traversed by a number of faults of great magnitude, it is possible that these fragments with Jurassic fossils, so abundant in the Elginshire drifts, are not far distant from their parent rocks, which may, indeed, in places, underlie the vast masses of Boulder-clay which mask the country.

§ 5. *The Upper Lias.*

At this horizon we have an unfortunate gap, the only complete one, in the series of beautiful sections of the Jurassic strata in Sutherland. It is quite possible that the very thick series of estuarine strata (sandstones, shales, and coals) which underlies the Middle Oolites of this district, may represent both the Lower Oolites and the Upper Lias also. That the latter era in the east of Scot-

land was either marked by the deposition of estuarine strata, or is totally unrepresented, is rendered highly probable by the fact that, among the numerous Jurassic fossils derived from the drift, I have never been able to find a single example of the very characteristic and well-marked Upper Lias forms.

§ 6. *The Lower Oolite.*

In Sutherland the place of the Lower Oolites is occupied by a thick mass of sandstones, shales, and coals, exhibiting many evidences of deposition under estuarine conditions. This series of strata is directly and conformably overlain by a great thickness of marine strata, representing the lower portions of the Middle Oolite. The great series of estuarine beds is thus proved to be older than the Middle Oolite by the fact that the lowest of the marine strata is, as we shall show hereafter, a bed representing the Kelloway Rock, and containing a fauna which enables us to refer it without doubt to the *lowest* zone of the Middle Oolite. That the estuarine beds, in part at least, represent the Lower Oolites, is confirmed by the fossils found in one of the marine beds included in the series. We have already pointed out that there are reasons for supposing that this estuarine series, which is certainly of great thickness, and of which the base has never been reached, may represent the Upper Lias as well as the Lower Oolite. There is, unfortunately, no point at which the relations of this set of beds with the known Liassic strata of the district can be observed.

These estuarine strata, as might be anticipated from their mode of origin, are very inconstant in character, so that sections at short distances from one another often exhibit surprising differences in the order and thickness of the strata passed through. The highest beds of the series were very carefully studied by Mr. Alexander Robertson, who laid accounts of his observations before this Society in 1843 * and 1846 †.

The following is a generalized section of this series of beds so far as it is known at Brora:—

	ft.	in.
"Roof-bed" of the coal. Base of the Middle Oolite (marine).		
(1) Main bed of coal. Sometimes a well-formed coal of good quality, at others approaching more in character to a lignite. In places it is seen to be wholly made up of the crushed stems of *Equisetites columnaris*, Brongn. This bed of coal contains in its midst a band of pyrites about 6 inches thick, which greatly detracts from the value of the seam. Maximum thickness	3	6
(2) Beds of black highly carbonaceous shale, often crowded with plant-remains, and alternating with thin bands of crushed shells (*Unio*, *Cyrena*, *Perna*, *Ostrea*, &c., and *Cyprides*). In some of the beds the scales and teeth of fishes abound (*Lepidotus*, *Semiotus*, *Pholidophorus*, *Hybodus*, *Acrodus*, &c.); and these occasionally form thin bone-beds. This series of beds includes in its upper part several beds of coal, varying in thickness from 16 inches downwards; but these do not appear to be so constant as the main		

* Proc. Geol. Soc. vol. iv. p. 173.

† Quart. Journ. Geol. Soc. vol. iii. (1847), p. 113.

	ft.	in.
seam. (These beds, from their resemblance in mineral character to some of the Wealden strata, have been identified with that formation)	26	0
(3) Beds of brown, greenish-grey, drab, and black, somewhat sandy clays (fire-clays), with seams of light-coloured argillaceous limestone, sometimes in nodules and at other times forming continuous bands. These beds contain some thin seams of imperfect coal, much mingled with pyrites. Fossils are rare in them; but occasional *Cyrenæ* or dwarfed *Ostreæ* occur, indicating their estuarine character	96	0
(4) Coarse white sandstones	39	0
(5) Clays like 3	7	0
(6) White sandstone	25	0
(7) Alternations of sandstone and clay	37	6
(8) White sandstone (thickness unknown).		

This series of estuarine strata has been proved to the depth of about 230 feet; but its thickness is probably much greater.

The coal-bed (1) is seen on the shore at Brora, near the old salt-pans; and at this place it has frequently been dug, the overlying "roof-bed" having been often removed by blasting; it now forms a very conspicuous reef on the shore at low water. Along the shore opposite and to the northward of this outcrop, a number of shallow pits have been sunk in the Inverbrora * Links at various dates since 1598 for working this bed and those a short distance below. The sites of many of these old pits can still be traced. In the valley of the river Brora, and at a distance of rather more than half a mile from its mouth, pits have been sunk to this coal-seam, which is there about 230 feet from the surface. The same bed of coal is repeated by a fault to the southward, and is seen in the cliff at Strathsteven, and possibly also at Clayside.

The series (2) is that described by Mr. Robertson as so remarkably illustrating the fresh-water origin of some of the beds. I saw it well exposed in a trial-hole at Strathsteven cliff. It can only be examined in artificial sections. The carbonaceous shales below the main coal-seam are very inflammable; they have been tested, in order to discover if they will yield illuminating oils like that obtained from the celebrated Torbane-hill mineral. The result of these trials, however, was not encouraging.

The beds of (3) have been exposed in several borings in search of coal; and they can also be fairly well traced on the shore, where the harder bands form reefs. During my residence at Brora I had an excellent opportunity of studying the nature and succession of the beds in a shaft and boring which were carried to a depth of 75 feet, in a futile endeavour to find coal.

The strata (4 to 8) can be traced on the shore, and were also penetrated by a boring in 1770. The sandstones (8) are evidently of great thickness. As we trace the strata to the southward along

* It may be well to mention that the name of Inverbrora was originally given to the fishing-village at the mouth of the river Brora. At the present time the name is applied to a farm at some distance inland.

the shore, we find their strike to change gradually from N. by E. and S. by W. to E.N.E. and W.S.W.; it is difficult to determine whether the thick masses of sandstone which are seen in the cliffs at Strathsteven, and which are worn into caves at Sputie Bay, regularly underlie the beds already enumerated; but it is probable that such is the case. On the shore at Strathsteven beds of clay and argillaceous limestone, containing a bed of coal about 18 inches thick, are seen. Near this point, the sandstones, which are usually very destitute of any trace of fossils, contain a few casts of marine shells in one of the beds. These are, unfortunately, very badly preserved as casts only, and rarely capable of specific determination.

Quenstedtia oblita (?), *Phil.*, sp.
Lucina, sp.
Trigonia, sp. (cast).
Astarte elegans (?), *Sow.*
Myacites decurtatus, *Phil.*, sp.
Pecten (ribbed species).
—— articulatus, *Schloth.*
—— demissus (?), *Phil.*
Large masses of wood (casts).

Obscure as these fossils are for the most part, there can be little doubt that the beds which yield them belong to the Lower Oolite.

The thick masses of sandstone which are seen in the Strathsteven cliffs exhibit much false-bedding, and often many seams of carbonaceous matter; they yield a good and easily worked freestone, hardening rapidly on exposure, which was once extensively dug at the Cleat quarries. The opening of the quarries in the Triassic sandstones on the south side of the Moray Firth, at Covesea, Hopeman, &c., has caused the almost total abandonment of the Sutherland quarries, a result due not so much to the superiority of the rock at the former localities as to the greater facilities there both for its shipment and land transport.

The sandstones about Strathsteven present the usual characters of the arenaceous type of estuarine series. The stratification is often obscure; the beds appear to dip S.E. 20° near the Cleat quarry. Sometimes the rock is ferruginous, and when exposed in reefs on the shore assumes a bright red colour. Two borings, of nearly 200 feet, have been put down in these beds at Strathsteven. One of these, made by Mr. William Miller in 1798, by the side of the parliamentary road, gave the following section:—

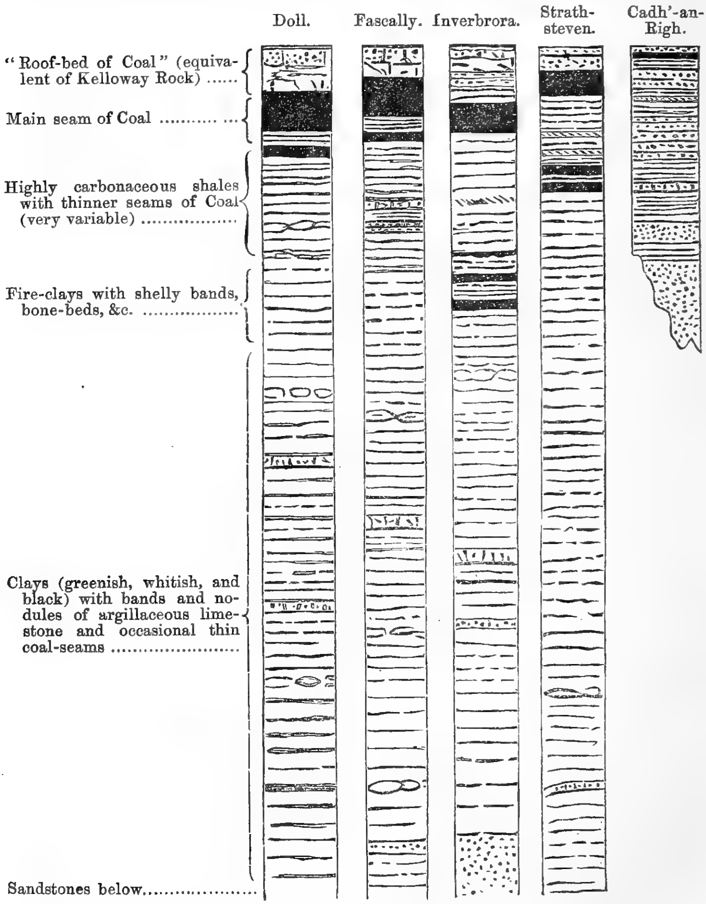
	ft.	in.
"Various metals"	31	0
Soft rotten freestone	18	2
Hard white freestone	109	6
Limestone	4	6
"Whinstone" (Cherty grit?)	1	4
"Blae or Till" (Blue clay)	5	1
"Whinstone"	0	8
Soft or rotten freestone	4	1
"Whinstone" (not cut through)	2	5
Total	176	9

As already observed, the base of this series of strata has nowhere been reached by boring; and on account of the great transverse faults, which let down a patch of newer strata between Strathsteven

and Dunrobin, the relations of the great series of estuarine beds to the Liassic rocks cannot be seen.

In order to illustrate the variations in the thickness and order of succession of these estuarine strata, I subjoin a number of sections obtained by shafts and borings at various points, beginning in every case with the "Roof-bed"—that is, the lowest bed (marine) of the Middle Oolite (see fig. 15).

Fig. 15.—*Comparative vertical Sections of the Coal-bearing Strata of Lower Oolite age in Sutherland and Ross.* (Scale 20 ft. to 1 in.)



(1) Boring on shore at Inverbrora by John Pritchard, 1811:—

	ft.	in.
"Roof bed"	4	0
Blue bind	3	6

		ft.	in.
Main seam.	Coal, sooty, 2 inches Coal (very good, except 2 or 3 inches in the middle) 2ft. 4in. Coal 4 inches	2	10
Black bass		7	0
Blue bind		19	0
Coal		0	10
"A soft pricking coal" (carbonaceous shale?)		0	10
Coal		0	11
Blue bind (not cut through)		27	1

(2) Boring in Inverbrora Links by John Evans, 1770. (N.B. Commenced below the roof-bed and main seam of coal.):—

	ft.	in.
Soft blue "mettal" (or bind)	12	8
Coal, soft	0	4
Soft blue "mettal"	2	0
Coal, soft	1	2
Soft grey "mettal" (or bind)	60	0
White post or sandstone	1	6
Soft grey "mettal" with girdles (or balls)	5	0
Soft black "mettal"	1	6
Soft blue "mettal"	3	0
Soft "mettal"	0	6
Black "mettal" and coals	0	2
Grey "mettal stone" (or clunch)	6	0
Strong "mettal stone"	3	0
Soft grey "mettal" with girdles	15	6
White post or Freestone	39	0
Soft grey "mettal" (bind or clay)	7	0
White post with hard lumps	25	0
Grey "mettal stone" with post girdles	27	6
White post or sandstone	2	6

(3) Boring in Inverbrora Links to the northward of the last, by John Evans, 1770:—

		ft.	in.
Blue sandy bind with shells Grey post (or sandstone) 9 inches Whinstone (or coarse limestone, 2 ft.	"Roof-bed."		
Grey post (or bind)		5	6
Coal (with a little mixture of black stone, 2 ft. 6 in.) Coal, Parrot, 3 in.		2	9
Black stone (or coaly bass)		7	0
Grey stone (or bind) not cut through		6	0

(4) Boring for coal at Water of Brora (Fascally), 1811:—

	ft.	in.
"Roof-bed"	4	4
Hard caking coal (main seam)	3	2
Black clunch	2	0
Hard splent coal	1	4
Black burning shale, like Cannel coal	6	7
Very hard stone	1	2
Black shale	2	0
Very hard stone	0	$2\frac{1}{2}$
Soft black shale speckled with white powdery matter (shelly band)	0	2
Hard black burning shale	4	2

(5) Boring for coal, Engine Pit, south of the river Brora, by William Hughes, 1814:—

	ft.	in.
"Roof-bed"	5	0
Main coal	3	8
Bituminous shale	2	0
Slate coal with pyrites, not workable	1	4
Fine clay alternating with shale	90	0

(6) Section exposed in the coal-workings at Strathsteven Cliffs, where the strata are faulted against the Strathsteven sandstone; observed 1872:—

	ft.	in.
"Roof-bed," hard greenish sandstone weathering brown, full of shells, *Myacites recurvus*, Phil., *Astarte minima?* Phil., *Gresslya peregrina*, Phil., &c. Many small pebbles of the size of peas	3	0
Greenish sandy clay. seen		
Bed of coal (main seam) with a band of pyrites in its midst	2	6
Dark-coloured bituminous clay, with many compressed Equisetites, and several thin seams of white sand	5 to 6 ft.	
Seam of white shells—*Perna* very abundant, also *Cyrena*, &c., and *Cypris*	0	3
Black clay, with many flattened specimens of *Equisetites* coated with pyrites, many plant-remains and coaly seams, scales of *Lepidotus* ...	1	2
White seam crowded with shells of *Perna*, *Ostrea*, *Cyrena*, *Cypris*, &c., very variable in thickness	1 in. to 5 in.	
Black clay, with a band of shells (*Unio?*) at the bottom	1	3
Coal seam (*made up of stems of Equisetites*)	10 in. to 12 in.	
Black clay } Thin white shelly seam }	1	0
Coal seam	1	0
Black clay with nodules of pyrites and many plant-remains.		

These strata are very irregular; the coals vary in thickness in the course of a few yards; and the shelly bands become split up and unite again in places. The strata are greatly disturbed, being near a fault (which was proved by these workings), and dip N. 37°.

(7) Boring at Clayside, probably in the same set of beds, the "roof-bed" not being seen, however; 1872:—

	ft.	in.
Coal of fair quality (thickness not ascertained) immediately underlying drift.		
Stiff dark-coloured clay	20	6
White sandy stone	1	6
Sandy light-coloured fine clay	3	6
White sandy rock	2	0

(8) The last section which I shall notice is that of Cadh'-an-Righ, on the Ross-shire coast, at a distance of 19 miles from Brora; this is interesting, as showing the differences which have taken place in the strata, and the way the coal has almost thinned out. (See fig. 8, p. 125.)

	ft.	in.
"Roof-bed" with fossils	1	0
Coal (main seam), a poor carbonaceous band	4 or 5 in.	
Carbonaceous clay	2	0
White sandstone with plants	2	0

	ft.	in.
Dark grey clay with *Cyrena*	1	0
Hard white band, made up of shells, *Cyrena*, *Perna*, &c. (same species as at Brora)	0	9
Dark grey clay	2	6
Band of argillaceous limestone	0	6
Greenish grey sandy clay passing into green sandstone	3	0
Light-coloured argillaceous limestone	1	0
Light-grey indurated fire-clay	2	0
Argillaceous limestone	0	9
White sandstone ... about	20	0
Light-blue sandy clay (faulted against the Lower Old Red Sandstone and Conglomerate).		

The question of the economic value of the coal-seams of Sutherland need not be entered upon in this memoir. The former history of the mining operations in the district, a history, unfortunately, like that of the workings in the similar rocks of the north-east of Yorkshire, of almost continual disappointment and loss, has been already sketched, by both Sir Roderick Murchison * and Hugh Miller †. The possibility of the profitable working of these thin coal-seams, under the existing somewhat adverse conditions, is a question belonging solely to the mining engineer. I may state, however, that the present noble proprietor of the estates has determined that a trial of the capabilities of the district, under the most advantageous conditions possible, shall be made, so as finally to settle a question of so much importance in connexion with his extensive property in the Highlands. The old Brora mines are now being pumped out, and will in a short time be again in working. The reports which have been circulated of the discovery of new deposits of coal in the district are altogether destitute of foundation.

The last point at which we have to notice the existence of Lower Oolite strata in the east of Scotland is at Stotfield, in Elginshire. This highly interesting patch of fossiliferous rocks was brought under my notice by Dr. Gordon, of Birnie, to whom it has long been known. There is no reason whatever for doubting that the strata yielding the fossils here are *in situ*; and, as already pointed out (page 128, fig. 12), they appear to be faulted against the "Cherty rock of Stotfield" and the Reptiliferous Sandstone.

The rocks here appear to consist of soft greenish white sandstones, graduating into very hard quartzite-like rock, sometimes containing carbonaceous markings. These rocks frequently weather on the shore to a bright red colour. Only one bed, which can be traced for some distance along the shore, yields fossils; and these are almost all in the condition of casts. In all respects these Lower Oolite rocks in Elginshire agree very closely with their equivalents in Sutherland, which I have already described.

I am indebted to Mr. Grant, of Lossiemouth, who has spared no pains in making as complete a series as possible of the rather obscure but very highly interesting fossils of this rock at Stotfield,

* Trans. Geol. Soc. 2nd ser. vol. ii. pt. 2 (1826), p. 324.
† Sketch-book of Popular Geology (1859), p. 253.

for the opportunity of studying his collection. The following list of fossils shows that the beds certainly belong to the Lower Oolites, and probably to the division of the Inferior Oolite:—

Pholadomya oblita, *Lyc. & Mor.*	Myoconcha, sp.
Myacites calceiformis, *Phil.*, sp.	Modiola cuneata? *Sow.*
——, sp.	—— imbricata, *Sow.*
Homomya, sp.	Lima duplicata? *Sow.*
Anatina, sp.	Pecten demissus? *Phil.*
Astarte rhomboidalis, *Phil.*	Pteroperna, sp.
Cyprina Loweana (?), *Lyc. & Mor.*	Gervillia?
Cardium, sp.	Ostrea Sowerbyi, *Mor. & Lyc.*
Cypricardia caudata, *Lyc.*	Exogyra?
Lucina, sp.	Rhynchonella varians? *Sow.*
Arca, sp.	——, sp.
Tancredia angulata? *Phil.*, sp.	Plant-remains.
—— axiniformis, *Phil.*, sp.	Fucoid? markings.

The promontory of Burghead is formed by beds of coarse sandstones, often conglomeratic, faulted against the Reptiliferous Sandstone. The former, judging from their mineral characters, are not improbably of the same age as the similarly situated beds of Stotfield, but they have not yet, unfortunately, yielded any fossils.

§ 7. *The Middle Oolite.*

The Middle Oolite is very completely represented in Sutherland, by several series of marine beds alternating with estuarine strata, the whole attaining a great thickness. From the marine beds there have been obtained some very interesting and beautiful series of fossils, which enable us to identify several of those clearly marked zones of life which have been distinguished by Dr. Oppel in Suabia*, Professor Hébert in France†, and Dr. Wright in England‡. For a thickness of more than 300 feet we have a succession of purely marine strata, principally clays; and this part of the series perhaps more nearly resembles the equivalent beds in England than do any other strata exposed on the east coast of Scotland.

A. *Zone of* Ammonites calloviensis, *Wright.*—The lowest part of this marine series is formed by a well-marked and everywhere recognizable stratum, which we have already had occasion to mention (the "roof-bed" of the main coal-seam). It is usually about 5 feet thick, though subject to considerable variation in this respect, and consists of a hard more or less calcareous sandstone. In its upper part it is crowded with marine shells, and sometimes passes into a hard shelly limestone; in its lower part it is usually more purely arenaceous, is crowded with plant-remains, and forms a connecting link between the marine strata above and the terrestrial and estuarine beds below. The rock is throughout very ferruginous, being generally of a dark greenish-grey colour when dug under the clays, but weathering to a bright red tint upon the shore.

* Oppel, 'Juraformation' (1856–58) pp. 506, 615, &c.

† Hébert, 'Les Mers Anciennes,' etc. (1857) p. 44.

‡ Wright, "On the Correlation of the Jurassic Rocks of the Côte-d'Or and the Cotteswold Hills," Proc. Cotteswold Club, 1869.

The fossils of this rock, as is the case with those of so many of the Secondary beds of Sutherland, are often much distorted by pressure.

The bed was formerly quarried on the shore, and its more calcareous portions, which are almost wholly made up of shells, burnt for lime; but this use of the rock has long been abandoned. Portions of the bed too have been blown up with gunpowder, where it rises as a reef on the shore, in order that the coal-bed below it might be worked at low water. When the mines at Brora were in operation, considerable quantities of the rock were brought to the surface; and its fossils could then be easily obtained. The only points at which I have myself been able to see this rock and collect its fossils are the Inverbrora reefs and the mine at Strathsteven Cliff.

Sir Roderick Murchison appears to have regarded this bed, from its relation to the series containing the Coals, as the equivalent of the "Grey Limestone" (or "pier-stone" as he calls it) of Scarborough*, a bed which is now very generally admitted to form part of the Inferior Oolite. The true position of the "Roof-bed," however, was more correctly defined by Mr. Alexander Robertson in 1846 to be that of the "Kelloway Rock" of the Yorkshire coast. The annexed list of fossils will serve to satisfactorily establish this correlation, and to demonstrate the close parallelism which exists between this part of the series in Scotland and its equivalents in England.

Fossils of the "Roof-bed" of Brora ("Zone of Ammonites calloviensis*" of Dr. Wright).*

Belemnites Owenii, *Pratt*, var. Puzosianus, *D'Orb.*
—— ——, var. tornatilis, *Phil.*
Ammonites Gowerianus, *Sow.*
—— sublævis, *Sow.*
—— Kœnigi, *Sow.*
——, sp.
Rostellaria composita, *Sow.*
Alaria, sp.
Actæon retusus, *Phil.*
Cerithium muricatum, *Sow.*
Pholadomya Murchisoni, *Sow.*
—— acuticosta, *Sow.*
Anatina undulata, *Sow.*, sp.
Gresslya peregrina, *Phil.*, sp.
Myacites recurvus, *Phil.*, sp.
—— securiformis, *Phil.*, sp.
—— calceiformis, *Phil.*, sp.
Thracia, sp.
Goniomya v-scripta, *Sow.*, sp.
Cardium striatulum, *Sow.*
—— cognatum, *Phil.*
—— Crawfordii, *Leckenby.*
Cardium, spec. nov.
Isocardia tenera, *Sow.*
—— nitida, *Phil.*
Cypricardia, spec. nov.
Unicardium depressum, *Phil.*, sp.
Nucula, sp.
Corbula obscura, *Sow.*
—— oxfordensis, *D'Orb.*
Astarte minima, *Phil.*
Cucullæa concinna, *Phil.*
—— minima, *Leckenby.*
Arca, spec. nov.
Lucina lirata, *Phil.*
—— pulchra, *Bean.*
Trigonia elongata, *Sow.*
—— rupellensis, *D'Orb.*
—— irregularis, *Seeb.*
Modiola cuneata, *Sow.*, var.
—— bipartita, *Sow.*
—— imbricata, *Sow.*
Lima duplicata, *Sow.*
——, sp.
Pteropterna, spec. nov.

* *Vide* Trans. Geol. Soc. 2nd Ser. vol. ii. part 2, p. 297, where Murchison clearly explains that what he identified the roof-bed of Brora with is the bed now usually designated the Grey Limestone of Scarborough.

Gervillia aviculoides, *Sow.*, sp.
Avicula, sp.
Pecten lens, *Sow.*
—— demissus, *Phil.*
—— arcuatus, *Sow.*
—— annulatus? *Sow.*
——, sp.
Gryphæa dilatata, *Sow.*, var. β, *Phil.*
—— bilobata, *Sow.*
Ostrea Marshii, *Sow.*
—— archetypa, *Phil.*
—— Sowerbyi, *Lyc. et Mor.*
Tooth of a Saurian.
Wood (abundant).

The beds lying directly on the calcareous sandstone of the "roof-bed" consist of finely laminated sandy clay, with numerous crushed bivalves, including *Nucula nuda*, Phil., small species of *Pecten*, &c. They abound with specimens of the different varieties of *Belemnites Owenii*, Pratt, and also contain *Ammonites Gowerianus*, Sow., *A. calloviensis*, Sow., var., and *Gryphæa dilatata*, Sow. (small variety). These beds must, from their palæontological characters, be classed with the "roof-bed" in the lowest zone of the Middle Oolite, as representing the Kelloway rock of England.

At the section of Cadh'-an-Righ on the coast of Rosshire, already noticed (p. 125), the "roof-bed" is very distinctly seen, though, like the coal-seam on which it lies, it is greatly reduced in thickness. It consists of a sandy clay passing into a very hard ferruginous and argillaceous sandstone, becoming in places calcareous from the abundance of included fossil shells. The fossils are very numerous, but badly preserved, the substance of the shells being almost always in a soft and decomposed condition. The upper surface of the bed, which is not more than a foot thick, is completely made up of Belemnites of all sizes, crowded together in great profusion. In the abundance of Belemnites which it contains, the rock at Cadh'-an-Righ differs from that at Brora; but there is the most complete correspondence with regard to the rest of the fauna.

Fossils from the "Roof-bed" at Cadh'-an-Righ.

Belemnites Owenii, *Pratt*, var. tornatilis, *Phil.* Very abundant.
——, sp.
Ostrea Marshii, *Sow.*
Gryphæa dilatata, *Sow.* (small form).
Pecten demissus, *Phil.*
—— lens, *Sow.*
Perna quadrata.
Lima pectiniformis, *Schloth.*
Cucullæa.
Trigonia elongata, *Sow.*
—— irregularis, *Seeb.*
Myacites recurvus, *Phil.*, sp.
—— securiformis, *Phil.*, sp.
Gresslya peregrina, *Phil.*, sp.
Serpula.
Wood.

The roof-bed at this place, as at Brora, is covered by a thick series of marine beds, to be more particularly noticed hereafter.

B. *Zone of* Ammonites Jason, *Wright.*—The "roof-bed" at Brora is overlain by a thick mass of argillo-arenaceous strata, crowded with marine fossils. These are the strata pierced in the several coal-shafts. There are great discrepancies in the accounts which we possess of the beds passed through in the two principal shafts; but this may be accounted for (especially when we remember that one of the sections is the result of a boring) by the variable character of the beds, which throughout consist of combinations of sand and clay in varying proportions, so that it is often difficult to decide whether

a particular stratum should be called a sandy shale or an argillaceous sandstone. The thickness of beds passed through in the coal-shafts at Brora was about 230 feet, and adding 70 feet more for the clays seen in the river-cliff above the Fascally or Water-of-Brora pit, we obtain for the total thickness of the argillaceous series above the "Roof-bed" 300 feet. Some of the strata are well exposed in a bluff of the river Brora, a little to the west of the Salmon-cruives, where they are brought up in a double anticlinal fold (see fig. 4, p. 119), and the rocks can be examined by wading the river when it is low; other portions can be seen in a cliff to the eastward, and between the last point and the Water-of-Brora pit; and, lastly, the whole series is displayed, though under somewhat unfavourable conditions, in the reefs on the Inverbrora shore. The lower beds of this series have been shown to belong to the zone of *Ammonites calloviensis*.

In mineralogical characters the different portions of this great series of clays offer very great variations. Sometimes we find dark blue, highly pyritous, shaly clay, with septaria, the characters of which recall the Oxford Clay of England; in other places the beds contain much wood in the form of jet, while nearly all the fossils have disappeared through the decomposition of the pyrites by which they were mineralized; and throughout a considerable part of their thickness the strata consist of finely laminated and very sandy shale crowded with Belemnites, which often attain to a great size, and innumerable specimens of Ammonites, Gasteropoda, and Lamellibranchiata, lying compressed between the laminæ. Occasionally the beds last described pass into hard, fissile, bluish grey sandstone, containing the same fossils, but in a worse state of preservation.

About the geological horizon to which the greater part of this series of argillaceous beds belongs, there is fortunately no reason for entertaining doubt, the fossils, though often badly preserved, being very numerous and highly characteristic.

The Ammonites, which occur in great numbers, nearly all belong to the group of the *Ornati*; but these are associated with a few species of the groups of the *Armati* and *Planulati*. The Belemnites, which are conspicuous alike from their vast numbers and the great size which they attain, belong to the different varieties of *Belemnites Owenii* of Pratt; *Belemnites sulcatus*, Mill., also occurs, but is comparatively rare. Among the Gasteropoda we find *Cerithium muricatum*, Sow., and several species of *Alaria*; while the Conchifera are represented by many species, usually of small size, and often so crushed as to defy specific determination. Oyster-banks do not appear to occur in this series of beds, though scattered specimens of *Gryphœa dilatata*, Sow. (small variety), are sometimes found. Throughout the series wood, often in large masses, and converted into jet, occurs in considerable abundance.

The palæontological characters of these beds clearly indicate that they belong to a geological horizon which has been already studied at many points in Germany, France, and England, and known as the "Ornatenthon" or "brauner Jura α" of Quenstedt, the "zones of *Ammonite anceps* and *athleta*" of Oppel and Hébert, and

the "zone of *Ammonites Jason*" of Dr. Wright. Except in the somewhat more sandy character of the beds, this part of the Jurassic series in Sutherland is scarcely distinguishable, either in petrological or palæontological characters, from its equivalents in many parts of Suabia, France, and England.

The principal fossils of these beds, so far as they are known to me, are enumerated in the following list:—

Fossils of the Argillaceous series above the Brora Coal-series, (Ornatus-*clays, Zone of* Ammonites Jason, *Wright*).

Belemnites Owenii, *Pratt*, var. Puzosianus, *D'Orb.*
—— hastatus, *De Blainv.*
Ammonites ornatus, *Schloth.*
—— Jason, *Reinecke.*
—— Gulielmii, *Sow.*
—— Comptoni, *Pratt.*
—— Duncani, *Sow.*
—— Sedgvici, *Pratt.*
—— Lonsdalei, *Pratt.*
—— Elizabethæ, *Pratt.*
—— Bakeriæ, *Sow.*
—— Kœnigi, *Sow.*
—— Reginaldi (?), *Mor.*
—— athleta, *Phil.*
Chemnitzia heddingtonensis?, *Sow.*
Cerithium muricatum, *Sow.*, sp.
Alaria bispinosa, *Phil.*, sp.
——, sp.
Myacites, sp.
Thracia, sp.
Cardium, spec. nov.
Isocardia tenera, *Sow.*
Corbula oxfordensis, *D'Orb.*
Nucula, sp.
Lucina, sp.
Cucullæa, sp.
Avicula, sp.
Pecten, sp.
Gryphæa dilatata, *Sow.*, var.
Ostrea, sp.
Wood (very abundant).

The highest part of the argillaceous series passes up into the marine sandstone strata above by insensible gradations, the arenaceous elements by degrees preponderating over the argillaceous in the composition of the rock. These higher beds, forming the transition between the two series, are generally very unfossiliferous, and yield only an occasional Belemnite (*B. sulcatus*, Mill., or *B. Owenii*, Pratt) or cast of a bivalve. They consist of very sandy clays, with nodular bands of argillaceous limestone, and are well exposed, to the thickness of upwards of 70 feet, in the cutting above the Water-of-Brora (Fascally) coal-pit. The argillaceous limestone here was at one time burnt for lime; and near the same spot the clays were dug for brick-making.

The series of beds just described appears to be brought up again by the transverse fault already noticed to the south of Strathsteven, and is exposed in a number of trial-holes in the brickyard at Clayside, where, however, very few species of fossils have been obtained, these being almost entirely limited to some fragmentary specimens of *Belemnites sulcatus*, Mill., and *Belemnites Owenii*, Pratt. The clay can also be traced, at several points between Clayside and Dunrobin, underlying the marine sandstones to be afterwards more particularly noticed; here, however, they are only seen in a few road-side cuttings and in the burns.

At Cadh'-an-Righ, in Ross-shire, the roof-bed is covered by the following series of beds (Fig. 8, p. 125):—

(*a*) Dark blue, very finely laminated shale, with some bands and flattened

nodules of argillaceous ironstone, containing *Belemnites Owenii*, Pratt (abundant), *Ammonites* (crushed specimens).

(*b*) Somewhat more sandy clays; very imperfectly seen.

(*c*) Thick beds of blue, somewhat sandy shale, with some bands of argillaceous limestone and septaria. Fossils are not abundant: *Gryphæa dilatata*, Sow., (small variety); *Belemnites Owenii*, Pratt.

(*d*) "Roof-bed" of the Coal.

The great sandstone series between these clays and those representing the Coralline Oolite does not appear to be present at Cadh'-an-Righ. It is probable that by a small transverse fracture the "*Ornatus*-clays" of this place are thrown against the clays of the Coralline Oolite of Port-an-Righ.

C. *Zone of* Ammonites perarmatus, *Wright.*—The thick series of beds, with predominating argillaceous characters, which rests upon the roof-bed of the coal, is surmounted by, and passes up into a mass of fine-grained argillaceous sandstones, with marine fossils tolerably abundant, especially in its upper portion. These marine sandstones, which are about 25 feet thick, are well seen on both sides of the river Brora; on the right bank the beds are presented in two exposures, being bent over in an anticlinal, the dip being N. at 12° and S. at 8°. At this point the strata consist of very fine-grained brittle sandstone of a yellowish colour, mottled with streaks of grey. Occasionally certain layers and concretionary patches are found converted into an intensely hard compact quartzite-like rock, with a fine conchoidal fracture.

In these beds fossils are tolerably abundant, but almost always in the condition of casts, and frequently much distorted by pressure. The species which especially characterizes these beds by its great abundance is a *Lucina*, which was confounded by Sowerby with his *Lucina crassa*, a Neocomian form. Wood, sometimes in very large masses and always more or less crushed, abounds in these sandstones. Ammonites, Belemnites, Pectens, and other bivalves occur by no means rarely in these beds. The list of their fossils is as follows:—

Ammonites cordatus, *Sow.*
—— Sutherlandiæ, *Sow.*
—— excavatus, *Sow.*
—— perarmatus, *Sow.*
——, sp.
Belemnites sulcatus, *Mill.*
—— Owenii, *Pratt.*
Gryphæa dilatata, *Sow.*, var.
Exogyra nana, *Sow.*, sp.
Pecten fibrosus, *Sow.*
Pecten vimineus, *Sow.*
—— vagans, *Sow.*
—— demissus, *Phil.*
——, sp.
Pinna lanceolata, *Sow.*
Lucina (crassa, *Sow.*, pars).
Goniomya v-scripta, *Sow.*, sp.
Pholadomya, sp.
Wood.

On comparing this list of fossils with that from the clays below, we find that we have entered a new zone of life. The Ammonites of the group of the *Ornati* have wholly disappeared, and have been replaced by those of the group of the *Cordati*—those of the groups of the *Armati* and *Planulati* persisting, but being represented by other species. Among the Belemnites, *B. Owenii*, Pratt, and its varieties are here very rare, while *B. sulcatus*, Mill., has greatly increased in

abundance and become the predominant form. *Gryphœa dilatata* still continues in existence, but as a distinct and well-marked variety, while a number of Gasteropoda and Conchifera have disappeared, their places being taken by new forms. Other species of longer range lived on through both the periods, while some, which began in far earlier, persisted to much later times. All the palæontological characters of the beds point to the fact that we have reached the horizon known as the "zone of *Ammonites biarmatus*" of Oppel, the "zone of *Ammonites perarmatus* and *cordatus*" of Hébert, and the "zone of *Ammonites perarmatus*" of Wright.

In the gorge of the river Brora, at Fascally, the marine stratum just described is seen to be covered by a great thickness of sandstones, which dip to the east, at first at an angle of 12°; but as we rise in the series this inclination appears to be gradually reduced, till at last it is no more than 4°. These sandstones, the lower beds of which were quarried in order to obtain materials for the wheel-casings and other constructions about the Water-of-Brora coal-pit, must be estimated at not less than 400 feet thick. They yield no traces of marine shells, except in certain thin bands; but they contain much carbonaceous matter in places, with occasional thin coaly seams, and are evidently of *estuarine* origin.

At a height of about 80 feet from the base of this series of sandstones I found a band containing casts of *Pecten*, *Myacites*, and other marine shells, not sufficiently well preserved to enable me to determine the species. About 100 feet higher another marine band occurs, with numerous casts of *Avicula braamburiensis*, Sow., and other shells, too obscure for identification. The highest beds of the sandstone series also contain marine shells in the condition of casts, including *Gryphœa dilatata*, Sow. (large var.), *Pecten fibrosus*, Sow., *Pecten vimineus*, Sow., *Pecten*, sp., *Avicula*, sp., *Myacites*, sp., &c., and form a transition to the marine series above. These beds of sandstone with marine shells are quarried on the left bank of the Brora, a little below the bridge. It is quite possible that, in the thick mass of estuarine sandstones just noticed, other marine bands may occur which have not yet been detected.

The great series of sandstone-strata which we have been describing is bent over towards the north in an anticlinal; this may be traced by observing the dips in the various pits opened on Braamberry and Hare Hills. The lowest marine beds, immediately above the clays, assume at their northern extension a somewhat different character locally, and consist of a hard, brittle, fine-grained sandstone full of casts of fossils. This sandstone has been very extensively dug in the Clynlish or Hare-Hill quarries, and has been employed in the construction of London Bridge and in many local erections, such as Dunrobin Castle, the colossal statue by Chantrey on the top of Beinn-a-Bhraggie, &c. It can be obtained in blocks of great size, is easily worked, and is of a beautiful white colour. In places the rock passes into an intensely hard compact material, like quartzite, which was, in the early part of this century, used by the local militia for making gun-flints, and, as my friend Mr. Joass showed me by a large

series of specimens in the Dunrobin Museum, was extensively employed in prehistoric times as a substitute for flint in making arrowheads, knives, and other weapons and implements.

The hard sandstone rock, where exposed at the surface on Hare Hill, has retained in a remarkably beautiful manner the striation and grooving impressed upon it by the great Strathbrora glacier, of which this hill at one time evidently formed the northern boundary. Whenever the turf and soil are removed from the surface of the hill, these markings, in a beautiful state of preservation, are revealed to view.

The casts of the exterior and interior of shells, which, however, are often distorted by pressure, are retained in a most perfect manner by this fine-grained rock; and the number of species yielded by it is very considerable. The fauna, however, though more numerous, is evidently the same as that we have already noticed as obtained from the yellow and grey sandstones at Fascally.

The following is the list of the Clynlish or Braamberry-Hill fossils which I have been able to examine:—

Belemnites sulcatus, *Mill.*
—— Owenii, *Pratt.*
Ammonites perarmatus, *Sow.*
—— ——, var. (Edwardsianus, *D'Orb.*).
—— ——, var. (A. Babeanus, *D'Orb.*).
—— ——, var. (A. rupellensis, *D'Orb.*
—— cordatus, *Sow.*
—— excavatus, *Sow.*, var.
—— plicatilis, *Phil.*
—— Achilles, *D'Orb.*
—— Sutherlandiæ, *Sow.*
—— lunula, *Ziet.*
—— anceps albus, *Quenst.* (A. coronatus, *D'Orb.*, var.).
Aptychus, sp.
Pleurotomaria, sp.
Trochus tornatilis, *Phil.*
Turbo funiculatus, *Phil.*
Phasianella, sp.
Chemnitzia, sp.
Pholadomya simplex, *Phil.*
——, spec. nov.
Myacites securiformis, *Phil.*, sp.
—— decurtatus, *Phil.*
—— calceiformis ?, *Phil.*, sp.
Goniomya v-scripta, *Sow.*, sp.
Gresslya.
Mya, sp.
Thracia depressa, *Sow.*, var.
Sowerbya triangularis, *Phil.*, sp.
Lithodomus (crypts).
Tancredia, sp.
Cypricardia, sp.
Cardium (truncatum, *Sow.* ??, pars).
Lucina (crassa, *Sow.* ?, pars).
Cucullæa pectinata ?, *Phil.*
Trigonia Joassi, *Lyc.* (spec. nov.).
Modiola bipartita, *Sow.*
Modiola cuneata, *Sow.*, var.
Perna mytiloides, *Sow.*
Gervillia, sp.
Pteroperna, sp.
Lima læviuscula, *Sow.*
—— pectiniformis, *Schloth.*
——, sp.
Pinna lanceolata, *Sow.*
Avicula braamburiensis, *Sow.*
—— expansa, *Phil.*, var.
Hinnites, sp.
Pecten lens, *Sow.*
—— vimineus, *Sow.*
—— fibrosus, *Sow.*
—— vagans, *Sow.*
—— demissus, *Phil.*
—— inæquicostatus, *Phil.*
—— subfibrosus, *Sow.*
——, sp.
Placunopsis (near jurensis, *Lyc.*).
——, sp.
Gryphæa dilatata, *Sow.*, var. bullata, *Phil.*
Exogyra nana, *Sow.*, sp.
Ostrea Rœmeri, *Quenst.* (O. duriuscula ?, *Bean, in Phil.*).
Terebratula bisuffarcinata, *Schloth.*
Waldheimia, sp.
Acrosalenia (spines).
Equisetites, sp.
Bucklandia Milleriana, *Carr.*
Yatesia Joassiana, *Carr.*
—— crassa, *Carr.*
Casts of wood, often in large masses, and sometimes perforated in all directions by worm-tubes and crypts of Mollusca.

The interesting Cycads derived from these beds, some of which have been described by Mr. Carruthers (*vide* Trans. Linn. Soc. xxvi. 1870, p. 675, pls. 54 & 63) are, like the other vegetables found in the rock, evidently drift timber, which after long floating in the open sea, and being subjected to the borings of numerous marine creatures, became at last buried and fossilized.

Above the Clynlish quarries, where the beds dip N.E. at an angle of from 8° to 9°, various beds of stone, without shells, but with much wood and carbonaceous matter, occur. A pit in these estuarine sandstones, which are evidently the same with those exposed in the gorge of the Brora, is open in Braamberry-Hill Wood; and formerly some of the harder and coarser beds were quarried for millstones. In one of the small openings in the beds of sandstone capping Braamberry Hill (of which a number were opened in order to test the suitability of the ground for a cemetery), stone with casts of shells was exposed, belonging probably to one of the marine bands of the series.

The lower part of the same great series of marine and estuarine sandstones is exposed, though not very favourably for examination, in the reefs at Brora Point.

Near Uppat the same series of sandstones is developed. Some of the pits and roadside sections expose only unfossiliferous sandstones with seams of carbonaceous matter; but in a small pit in the woods near Uppat House, I collected

Pecten vimineus, *Sow.*
—— fibrosus, *Sow.*
—— lens, *Sow.*
Lucina (crassa, *Sow.*, pars).
Modiola bipartita, *Sow.*
Perna mytiloides, *Sow.*
Gresslya, sp.
Wood.

In the deer-forest above Dunrobin Castle, and at an elevation of upwards of 500 feet above the sea-level, several small openings in the wood expose the same series of sandstones. In a pit situated due north of the Castle, to which I was first directed by my friend Mr. Joass, the following species were obtained:—

Ammonites cordatus, *Sow.*
Belemnites sulcatus, *Mill.*
Trochus, sp.
Pecten vagans, *Sow.*
——, sp.
Pinna lanceolata, *Sow.*
Avicula braamburiensis, *Sow.*
——, sp.
Modiola bipartita, *Sow.*
Gervillia.
Lucina (crassa, *Sow.*, pars). (Very abundant.)
Astarte.
Goniomya v-scripta, *Sow.*, sp.
Gresslya, sp.

Another small pit, a little to the north of the last, exposes other white sandstones with a few casts of fossils, including

Chemnitzia, sp.
Pecten fibrosus, *Sow.*
—— vagans, *Sow.*
Perna, sp.
Lucina, sp.

and other bivalves in casts, the species being indeterminable.

Below these sandstone strata, which are also exposed in some

road-side banks, &c., occur the argillaceous beds which are dug at Clayside as already noticed.

A little to the north of Bakkies there is in the deer-forest an old and deep pit, lying N.N.W. from Dunrobin Castle. The strata seen here consist of coarse white or slightly ferruginous sandstone, occasionally passing into grit, with a few pebbles of white quartzite scattered through them. Some of the finer beds are indurated into a kind of pseudo-quartzite. There is about 40 feet of rock exposed in this quarry, the beds dipping E.S.E. 30°. The fossils obtained here consist only of a few very unsatisfactory casts of *Ceromya*?, *Myacites*, or *Homomya*, and *Modiola* (?). I am unable to decide whether these beds belong to the Middle or the Lower Oolite; and the same doubt exists about some of the beds exposed in the neighbourhood of Strathsteven.

These Jurassic sandstones exposed inland often dip at considerable angles, and are greatly disturbed; probably also they are affected by a series of fractures transverse to the great fault which has thrown them against the Palæozoic rocks. In the tract where they occur, which, besides being much masked by drift, is almost wholly covered by woods, it is impossible to trace and map the position of these smaller faults, though the effects produced by them are often sufficiently obvious.

D. *Coralline Oolite.*—The great series of sandstones just described, of which the total thickness cannot be less than 400 feet, is probably, like others of the kind in Sutherland, of estuarine origin; the thin bands containing casts of marine shells, which we have described in it, marking only temporary and local incursions of the sea. It is succeeded, however, by another set of deposits, in which beds with marine characters predominate. These are unfortunately not well exposed, so as to admit of the exact tracing of the succession and thickness of the several strata. At the time of Farey's survey of the district, in 1813, there were a number of pits in which the limestones and clays of this series of beds were dug; and by means of trial-holes he succeeded in tracing their lines of outcrop across the country. Some of these pits appear to have been still open in 1826, when Sir Roderick Murchison made his examination of the district; but they are now all closed. Portions of the series, however, are visible on both banks of the Brora, below the bridge and at Ardassie Point, though, as the rocks are very imperfectly exposed and appear also to be faulted, there is some difficulty in determining their order of succession and thickness.

Lying upon the highest beds of the sandstone series, which, as we have seen, contain numerous casts of marine shells, there occurs a bed of bluish grey sandy limestone. This rock is exposed on the left bank of the Brora, but is now only very imperfectly seen; formerly, however, it was dug and burnt into lime; and the rock is said by Farey to be 12 feet thick. This bed and the other limestones of the series, when exposed at the surface, weather, by the removal of the calcareous matter in solution, into a very soft yellowish brown sandy material, of small specific gravity, formerly used for "rotten-

stone." Masses of these rocks, in a decomposed condition, are found in the Till at the top of the Hare-Hill Quarries. This bed of limestone is crowded with fossils, specimens of the very large variety of *Gryphæa dilatata* being very numerous; *Ostrea gregaria* also occurs in considerable abundance. Ammonites of the group of the *Cordati*, especially *Ammonites excavatus*, Sow., *A. vertebralis*, Sow., and the large compressed variety of *A. cordatus*, Sow., which becomes smooth with age, occur abundantly in this bed. Belemnites are rare, *B. abbreviatus*, Mill., being the only form collected. The genera *Pecten*, *Modiola*, *Cucullæa*, *Pholadomya*, &c. are represented by a number of species. This bed of limestone has been traced in the neighbourhood of Braamberry Hill for some distance; and some lime-pits were opened in it at this point. It may be necessary to mention that it was formerly the custom in the Highland districts to open pits wherever a small bed of limestone was found, and to burn the stone with peats; but the greater facilities of transport have caused the total abandonment of this practice.

The fossils of this limestone-bed are often much distorted by pressure; they are enumerated in the subjoined list.

Fossils of the Argillaceous limestone on the left bank of the Brora (Coralline Oolite).

Belemnites abbreviatus, *Mill.*
——, sp.
Ammonites cordatus, *Sow.*, var.
—— vertebralis, *Sow.*
—— excavatus, *Sow.*
—— Lamberti, *Sow.*
——, sp.
Aptychus, sp.
Pholadomya simplex, *Phil.*
——, spec. nov.
Myacites retusus, *Phil.*, sp.
Anatina undulata, *Sow.*, sp.
Goniomya v-scripta, *Sow.*, sp.
Thracia depressa, *Sow.*, var.
Isocardia, sp.
Cardium, sp.
Cucullæa, spec. nov.
Arca scabrella, *Rig. & Sauv.* (A. quadrisulcata ?, *Sow.*).
—— æmula, *Phil.*
——, sp.
Modiola bipartita, *Sow.*
Modiola cuneata, *Sow.*, var.
Lima læviuscula, *Sow.*
—— concentrica, *Sow.*
Pinna lanceolata, *Sow.*
—— mitis, *Phil.*
Avicula expansa, *Phil.*
Pecten lens, *Sow.*
—— demissus, *Phil.*
—— vimineus, *Sow.*
—— vagans, *Sow.*
—— subfibrosus, *Sow.*
——, sp.
Placunopsis inæqualis, *Phil.*, sp.
——, spec. nov.
Gryphæa dilatata, *Sow.*, var.
Ostrea Rœmeri, *Quenst.*
—— gregaria, *Sow.*
Rhynchonella varians, ? *Sow.*
Serpula, sp.
Fronds of ferns and other plant-remains.
Wood.

The limestones just described are covered by beds of clay, which, on the left bank of the Brora, appear to be thrown out by a fault, so that only a small portion of their thickness is seen; but on the right bank of the river they are well exposed and can be examined behind the curing-house, where the bank has been cut back to make room for the buildings. The beds seen here consist of dark-blue, more or less pyritous, sandy clay, with a few small septaria. Some portions of these clay-beds become extremely arenaceous, and are in-

durated into an imperfect rock; they contain numerous carbonaceous markings; but shells are by no means abundant in them. I collected, however, the following species:—

Belemnites (fragments).
Ammonites Lamberti, *Sow.*
Ostrea gregaria, *Sow.*
Pecten lens, *Sow.*
Pecten vagans?, *Sow.*
—— fibrosus, *Sow.*
—— vimineus, *Sow.*
Cucullæa, sp.

Clays, on this horizon, were at one time dug at several places about Braamberry Hill; but there are no exposures of them at the present time. A small wood here, however, bears the name of Claypit Plantation.

It appears probable from the descriptions of Farey, that another bed of limestone, weathering into "rottenstone" and similar to that below the clay-beds, was found above them; but I have nowhere succeeded in finding an exposure of it, so as to collect its fossils.

Above the second limestone bed we have a series of the ordinary white sandstones, with carbonaceous seams and markings. These seem to be similar in every respect to those so common in the district; they appear to exceed 60 feet in thickness, and to be wholly destitute of fossils, and they perhaps constitute a break in the series of marine deposits we are now describing. They are seen on both sides of the estuary of the Brora and in reefs at Ardassie Point.

At the last-mentioned locality the sandstone-beds are seen to be covered by an interesting series of argillaceous limestones of a light-blue colour, which alternate with dark-coloured clays and sandy limestones, yielding many fossils. Some of the beds are crowded with the large expanded form of *Gryphæa dilatata*, Sow.; and *Ostrea gregaria*, Sow., is also abundant. Ammonites of the group of the *Cordati* specially characterize these beds; while those of the group of the *Planulati*, such as *A. plicatilis*, Phil., also occur. The fauna, as will be seen from the annexed list, is not very different from that of the limestone below; many of the fossils are greatly distorted by pressure. The thickness of these beds exceeds 40 feet; they probably constitute the highest portion of the Middle Oolites in this district.

Fossils from the Reefs at Ardassie Point (Coralline Oolite).

Ammonites cordatus, *Sow.*, var.
—— vertebralis, *Sow.*
—— Lamberti, *Sow.*
—— excavatus, *Sow.*
—— plicatilis, *Phil.*
——, sp.
Nerinæa, sp.
Chemnitzia, sp.
Pholadomya simplex, *Phil.*
—— æqualis, *Sow.*
Goniomya v-scripta, *Sow.*, sp.
Myacites retusus, *Phil.*, sp.
Thracia depressa, *Sow.*, var.
Cardium, sp.
Cucullæa, spec. nov.
Arca æmula, *Phil.*
Trigonia corallina, *D'Orb.*
—— monilifera. *Ag.*
Modiola bipartita, *Sow.*
—— cuneata, *Sow.*, var.
Pinna lanceolata, *Sow.*
—— mitis, *Phil.*
Perna Murchisoni, *Forbes.*
Lima læviuscula, *Sow.*
—— concentrica, *Sow.*
Pecten demissus, *Phil.*
—— vagans, *Sow.*
—— lens, *Sow.*

Pecten subfibrosus, *Sow.*
—— vimineus, *Sow.*
——, spec. nov.
Placunopsis inæqualis, *Phil.*, sp.
——, spec. nov.
Gryphæa dilatata, *Sow.*, var.
Ostrea Rœmeri, *Quenst.*
Ostrea gregaria, *Sow.*
Serpula intestinalis, *Phil.*
——, sp.
Spine of Acrosalenia.
Cliona (crypts).
Ferns.
Wood and Plant-remains.

An examination of the faunas of the various limestones and clays above the thick series of estuarine sandstones of the gorge of the Brora shows that they all form part of the same marine series, the beds of white sandstone only marking a partial interruption of the marine conditions. The large series of fossils collected from these marine strata fortunately leaves no room for doubt as to their true geological horizon; the fauna is unmistakably that of the Coralline Oolite of England. The correspondence of the fossils of the Scotch beds with those of the English, in spite of the difference of mineral characters, is very striking.

Thus the Middle Oolite series of Sutherland is seen to be very fully developed, attaining a thickness of at least from 800 to 900 feet, of which about one half is made up of marine strata, and the other half of estuarine.

South of Shandwick Bay, at Port-an-Righ, on the coast of Ross-shire, other beds of the age of the English Coralline Oolite, and differing but slightly in mineral character from those of Sutherland, are found. They consist of dark-blue shales, alternating with and passing into beds of sandy argillaceous limestone. The clays contain some septaria; and towards the middle of the series there are some beds of very hard and compact argillaceous limestone, which weather to a red colour (figs. 6 & 7, pp. 124 & 125).

Fossils are not generally very abundant in these beds; but the hard limestone bands are in places found to be crowded with Ammonites. The most conspicuous fossil is the gigantic expanded variety of *Gryphæa dilatata*, Sow.

The thickness of beds exposed here is not very great, their strike being generally parallel to the shore; the breadth of their outcrop probably does not exceed 100 yards, the dip being from 20° to 30°.

The manner in which these beds are faulted against the Old Red Sandstone, and the curious way in which they are bent, contorted, and broken up by small faults has been already described (see p. 123).

These beds have hitherto been usually classed with the Lias; but the following list of fossils contained in them proves conclusively that their true horizon is that of the English Coralline Oolite.

List of Fossils from the Clays and Limestones at Port-an-Righ, south of Shandwick Bay, Ross-shire (Coralline Oolite).

Belemnites sulcatus, *Mill.*
—— abbreviatus, *Mill.*
Ammonites cordatus, *Sow.*, varieties.
—— excavatus, *Sow.*
Ammonites vertebralis, *Sow.*
—— Reginaldi, ? *Mor.*
—— plicatilis, *Phil.*
—— Achilles, *D'Orb.*

Ammonites, sp.
Perna mytiloides, *Lam.*
Pecten demissus, *Phil.*
Gryphæa dilatata, *Sow.*, var.
Ostrea gregaria, *Sow.*
Serpula, sp.

Although the Middle Oolite strata have not been found *in situ* on the south side of the Moray Firth, yet fragments of them are remarkably abundant in the Boulder-clays of that area. In many places, as in the bed of Loch Spynie, fragments of the coals, unfossiliferous sandstones, &c. of this series abound, and in one case induced the proprietor of the land to undertake a boring in the hope of finding a bed of coal. Fragments of the blue Oxfordian shales, crowded with their characteristic fossils, are also abundant in the Till; and rounded waterworn masses of them are often picked up on the shore. Such masses of Oxfordian beds with fossils have been found, sometimes mingled with fragments of other rocks, at a number of points in Elginshire, at the brickyard of Blackpots, near Banff (where the reconstructed clays are dug for brickmaking), and at the Plaidy cutting, between Macduff and Turriff, in the county of Aberdeen.

In the parish of Urquhart*, in the county of Elgin, there are portions of the Boulder-clay almost made up of fragments of the Oxfordian strata, crowded with the characteristic fossils. These have been very carefully collected by the Rev. James Morrison; and from the specimens preserved in his private collection, and those placed by him in the museums at Elgin and Marischal College, Aberdeen, I have been able to compile the following list:—

List of Oxfordian Fossils from Drifted Masses (Boulders) at Urquhart (Elginshire).

(1) In sandy stone like the "Roof-bed" of Brora:—

Ostrea Marshii, *Sow.*
Gervillia aviculoides, *Sow.*, sp.
Modiola gibbosa, *Sow.?*
Cucullæa concinna, *Phil.*
—— minima?, *Leckenby.*
Isocardia tenera, *Sow.*
Myoconcha, sp.
Myacites recurvus, *Phil.*, sp.
—— calceiformis, *Phil.*, sp.
Gresslya peregrina, *Phil.*, sp.
Perna Murchisonii?, *Forbes.*
Goniomya v-scripta, *Sow.*, sp.

(2) In dark-blue clays:—

Belemnites Owenii, *Pratt.*
—— sulcatus, *Mill.*
Ammonites cordatus, *Sow.*
—— excavatus, *Sow.*
—— Lamberti, *Sow.*
Alaria, sp.
Myacites recurvus, *Phil.*, sp.
Pholadomya, sp.
Goniomya v-scripta, *Sow.*
Trigonia clavellata, *Sow.*, sp.
Modiola bipartita, *Sow.*
—— cuneata, *Sow.*, var.
Gervillia, sp.
Pinna lanceolata, *Sow.*
Perna mytiloides, *Lam.*
Pecten vimineus, *Sow.*
—— lens, *Sow.*
—— fibrosus, *Sow.*
—— demissus, *Phil.*
Placunopsis inæqualis?, *Phil.*, sp.
——, spec. nov.
——, spec. nov.
Gryphæa dilatata, *Sow.*
—— ——, var.
Exogyra nana, *Sow.*
Ostrea Rœmeri, *Quenst.*
—— gregaria, *Sow.*
Serpula intestinalis, *Phil.*

* "On Fossil Remains found at Urquhart, near Elgin," by the Rev. James Morrison, Rep. Brit. Assoc. 1859, p. 263.

Serpula, sp.	Wood.
Crustacean remains.	

Among the Oxfordian fossils obtained from the drifts of Elginshire and the adjoining counties there occur many very interesting and not a few new forms. Among these may be especially mentioned several beautiful species of *Placunopsis*.

The clay of Blackpots, near Banff, yields a number of Oxfordian fossils, such as *Gryphæa dilatata*, Sow., *Belemnites Owenii*, Pratt, and *Belemnites abbreviatus*, Mill.; but with these are mingled Upper-Oolite forms like *Ammonites mutabilis*, Sow., *Lima concentrica*, Sow., and many others. The clay here is certainly a drift deposit, as was shown by Mr. Prestwich* and Hugh Miller†, and not a mass of Oolite *in situ*, as it had previously been considered.

§ 8. *The Upper Oolite.*

The Upper Oolites, which are now for the first time recognized as existing in the northern part of this island, are represented by a great series of strata of shales, sandstones, and grits, the whole of which indicate the prevalence of littoral and estuarine conditions during their deposition. They attain to a thickness of probably not less than 1000 feet, and yield a splendid fauna and flora.

The base of the Upper Oolites is, so far as I know, exposed only at one point in Sutherland, namely the vicinity of Braamberry Hill. At this place, unfortunately, the quarries which formerly existed are now all closed. Above the beds of limestone, already noticed as representing the Coralline Oolite, are some white sandstones with marine shells, including *Ammonites biplex*, Sow., and some other species. I have been able to examine a few fossils which have been preserved from a quarry in these beds near Clynlish; and although the question is not placed altogether beyond doubt by them, yet the balance of evidence is decidedly in favour of our considering them as belonging to the *Upper*, rather than to the *Middle*, Oolites.

Above these marine sandstones are others without fossils, and probably of estuarine origin, which contain some beds of clay, and bands with much carbonaceous matter. These strata are very imperfectly exposed. Perhaps the beds seen to be so curiously contorted in the Clyne-Kirk gorge (see fig. 2, page 118), where they are faulted against the Silurian rocks, belong to this part of the series. The upper part of the sandstones is exhibited north of Allt-na-cuil, where, the strata being bent in opposite directions, the rocks in question are the lowest exposed, and form the apex of a great anticlinal fold.

These unfossiliferous sandstones are succeeded by others contain-taining scattered quartz pebbles, and sometimes passing into a very coarse grit or conglomerate; the latter are often crowded with casts of marine fossils, which, however, are usually very imperfectly preserved. Masses of wood, also in the condition of casts, and often of

* Proc. Geol. Soc. vol. ii. p. 545.

† Rambles of a Geologist, 1858.

large size, abound, as in the Clynlish stone; but it is composed of much coarser materials than that rock. Slabs also occur, traversed by ripple-markings and worm-tracks, or covered with casts of vegetable fragments and small shells. The strata sometimes greatly resemble the Collyweston, Stonesfield, and similar "slates" of England, and present clear indications of having been deposited under very shallow-water conditions.

These marine beds are best seen at Allt-na-cuil, where, both above and below the waterfall, there are quarries in this rock. They are also seen on the other side of the anticlinal referred to, where a cutting has been made on the Sutherland Railway. This rock forms a valuable building-stone for certain purposes. It is very soft when first quarried, hardens rapidly on exposure, and is very durable. Although of so much coarser texture, it appears, in its power of resisting weathering action, to greatly resemble the celebrated "Roach-bed" of Portland, and, like it, is used for the copings of walls and similar situations.

The fauna of these beds shows that they belong unquestionably to the Upper Oolites, and is as follows:—

Fossils of the Marine Sandstones of Allt-na-cuil &c.
(Upper Oolites).

Belemnites obeliscus, ? *Phil.*
Ammonites Eudoxus, *D'Orb.*
—— biplex, *Sow*, ? var.
—— Achilles, *De Loriol* (non *D'Orb.*).
—— triplicatus, *Sow.*
—— mutabilis, *Sow.*
Natica, sp.
Arca, sp.
Avicula expansa, *Phil.*, var.
Perna subplana, *Etallon.*
Pteroperna, sp.
Pecten demissus, *Phil.*
—— articulatus, *Schloth.*
——, sp.
Hinnites inæquistriatus, *D'Orb.*
Ostrea Rœmeri, *Quenst.*
—— expansa, *Sow.*
—— deltoidea, *Sow.*
Rhynchonella pinguis?, *Röm.* (very abundant).
—— pectunculoides?, *Etallon.*
Serpula, sp.
Cidaris, sp. (spines).
——, sp.
Acrosalenia, sp. (spines).
Equisetites, sp.
Wood (abundant).
Fucoid markings?

These marine beds are overlain by a considerable thickness of strata, of estuarine origin, which are exhibited in the neighbourhood of Allt-Chollie (Colyburn), where, however, they are somewhat obscure, owing to the greatly contorted and crushed condition of the beds, which has been already described (page 118, fig. 3). On the opposite side of the anticlinal, however, between Allt-na-cuil and Lothbeg Point, they are much more favourably exposed for study. They are of very considerable thickness, several hundred feet at least, and consist of alternations of white sandstones, containing only a few plant-remains, and beds of very finely laminated, black, carbonaceous, sandy shales. In the lower part of the series the white sandstones predominate; but as we pass upwards the laminated argillaceous beds become of greater thickness, and at last form the principal part of the mass. In the highest beds, of which admirable sections are exposed at the artificial opening through which the

Lothbeg river now flows to the sea, and in the adjoining railway-cutting, the shales contain a few marine fossils crushed between the laminæ. These are as follows :—

Ammonites alternans, *Von Buch.*	Belemnites obeliscus, *Phil.*
—— flexuosus, *Münst.*	—— spicularis, *Phil.*
—— biplex, *Sow.*	Lima concentrica, *Sow.*, &c.

The Belemnites are nearly always fragmentary. Thus the series of estuarine beds just described graduates up into the marine strata above them.

At the cliff between Lothbeg River and Lothbeg Point the beds just described are seen to underlie and pass up into a set of hard sandstones and grits, alternating with finely laminated black shales. These beds, together with the limestones, with which in their upper part they alternate, were referred by Sir Roderick Murchison to the Lower Oolites, on account of the resemblance of some of the beds to the Forest-marble and Cornbrash of the south of England, though but very slight palæontological evidence was adduced in support of this correlation. The resemblance of some of these beds, in their mineral characters, to the English Forest-marble is certainly sufficiently marked; but this must be regarded as the result only of the similarity of conditions under which the two sets of beds were deposited—the broken condition of the shells, the abundance of wood and plant-remains, and the prevalence of certain genera of Mollusca indicating that in both cases the strata were deposited under littoral conditions. The fauna of these beds, however, like that of the marine sandstones several hundred feet below, yields unmistakable evidence that the whole of these strata, with the estuarine clays and sands between them, must be referred to the Upper Oolite.

This series of grits, shales, and limestones, which can be traced at the mouths of several small ravines at Achrimsdale, Clyne-Mill-town, and just north of Kintradwell, is admirably exposed, for a distance of 11 miles, in reefs on the shore, and also in some inland sections, at a great number of points between Kintradwell and Green-Table Point, and even northward in the county of Caithness. Bent into innumerable folds and broken up by many faults, as already described, the beds of this series are repeated again and again along the shore by Garty, Port Gower, Helmsdale, and Navidale. Owing to the superior hardness of the grit-beds of the series, these strata have resisted denudation, and form a number of small headlands, terminating in long reefs of rocks. As already described, these beds are singularly crumpled and broken. The softer shales and inter-bedded sandstone laminæ have in a great measure yielded to the forces to which they have been subjected; and where they have been planed away many beautiful examples of waved and contorted stratification, accompanied by small hitches or faults, are exhibited with all the clearness and distinctness of a geological diagram. The brittle sandstones, on the other hand, have by the same forces been crushed and broken into fragments; and angular masses of the harder portions of them lie in the greatest confusion, imbedded in a matrix

of sand formed by the grinding-up of the softer portions. In the reefs on the shore these crushed sandstones are sometimes found again completely indurated; and the masses then sometimes resemble walls of the rudest Cyclopean architecture. This apparently *brecciated* condition of the rock must not, however, be confounded with a phenomenon displayed in the same series of strata in their northern development, which is of a totally different character and origin, and will hereafter be particularly described.

This series of beds in many parts yields a considerable number of fossils. The limestones, which are sometimes wholly made up of specimens of *Exogyra nana*, Sow., and *Ostrea* (*Exogyra*) *Bruntrutana*, Thurm., in places contain also a considerable number of other species. Unfortunately, however, the majority of the shells are very fragmentary, or when entire are incapable of removal, owing to the hardness of the matrix and the decomposed condition of the shells. Small Gasteropods and spines of Echinoderms are very abundant; but entire specimens of this latter class seldom or never occur. Very conspicuous, too, in these beds are the gigantic *Rhynchonellæ* (*R. Sutherlandi*, Dav.). Great masses of drifted and waterworn coral, *Isastræa oblonga*, Edw. & Haime, also occur in them. The finely laminated clays contain in many places numerous crushed specimens of *Ammonites*, *Ostrea*, *Lima*, *Avicula*, *Pecten*, &c., and of the remarkable long slender Belemnites (*B. obeliscus*, Phil., and *B. spicularis*, Phil.), which are so characteristic of these beds *. The associated grits contain the same fossils, but in a much worse state of preservation, and nearly always as casts. The limestones of this series were formerly burnt in kilns on the shore at Port Gower, Helmsdale, and Navidale; but this use of them is now abandoned.

Very remarkable and interesting in connexion with these Upper Oolite strata is the large and beautiful flora which they yield. On splitting open some of the fissile grits and sandstones, leaves of Cycadean plants and fronds of ferns are found spread out as in an herbarium. Stems of Cycads, and large masses of wood, with cones and buds of Coniferæ, also occur. This interesting flora was first brought under the notice of geologists by Hugh Miller, by whom some of the more remarkable objects were figured in the last two chapters of his 'Testimony of the Rocks.' Among the beds of limestone, sandstone, grit, and laminated shale are sometimes found much carbonaceous matter, occasionally, as at Gartymore, forming thin and impure seams of lignite.

The thickness of this great series of beds can nowhere be exactly determined. A continuous section near the Allt-gharashtiemore exhibits a succession of over 500 feet; and the whole series is probably not less than twice that thickness.

The following is the list of fossils found in these strata:—

* I have already (page 110) noticed how erroneous information concerning the localities from which certain specimens were derived led to the Belemnites being referred to the Middle instead of the Upper Oolite in Prof. Phillips's Memoir.

List of Fossils from the Limestones, Grits, and Shales of the Upper Oolite of Sutherland (Kintradwell, Garty, Port Gower, Helmsdale, Navidale, &c.).

Plesiosaurus, sp.
Gyrodus Goweri, *Eg.*
Other fish-remains.
Belemnites abbreviatus, *Mill.*
—— obeliscus, *Phil.*
—— spicularis, *Phil.*
Ammonites triplicatus, *Sow.*
—— alternans, *von Buch.*
—— flexuosus, *Münst.*
—— Beaugrandi, *Sauv. et Rig.*
—— biplex, *Sow.*
—— ——, *Sow.*, var.
—— mutabilis, *Sow.*
—— Eudoxus, *D'Orb.*
—— Calisto, *D'Orb.*
—— autissiodorensis, *Cotteau.*
—— Achilles, *De Loriol* (non *D'Orb.*).
Cerithium, sp.
Chemnitzia, sp.
Nerita, sp.
Natica vespa, *De Loriol.*
Pleurotomaria, sp.
Pterocera, sp.
Turbo, sp.
Trochus, sp.
Lithodomus, sp.
Cardium Dufrenoyeum, *Buv.*
—— morinicum, *De Loriol.*
Lucina substriata, *Röm.*
Cucullæa, sp.
Astarte, spec. nov.
Lima concentrica, *Sow.*, sp.
Lima læviuscula, *Sow.*
Avicula expansa, *Phil.*, var.
Placunopsis, spec. nov.
Hinnites inæquistriatus, *D'Orb.*
Pecten vimineus, *Sow.*
——, sp.
——, sp.
Exogyra nana, *Sow.*
—— spiralis, *Goldf.*
Ostrea (Exogyra) Bruntrutana, *Thurm.*
—— Rœmeri, *Quenst.*
—— solitaria, *Sow.*
—— expansa, *Sow.*
—— gessoriacensis, *Sauv. et Rig.*
Rhynchonella Sutherlandi, *Dav.*
——, sp. allied to R. triplicosa, *Quenst.*
——, sp.
Terebratula Joassi, *Dav.*
Waldheimia humeralis, *Röm.*
Serpula Royeri, *De Loriol.*
——, sp.
Cidaris, sp. (spines).
—— —— (spines).
Acrosalenia, sp. (spines).
Isastræa oblonga, *Edw. & H.*
Thamnastræa, sp.
Bennettites Peachianus, *Carr.*
Various Cycads.
" Ferns.
" Coniferæ.

The beautiful flora of these beds, the age of which is now placed beyond all question as that of the Upper Oolite, will be made the subject of a critical study by Mr. Carruthers. It will form a new and highly interesting link in the history of vegetable life.

The shales, grits, and limestones just described are covered conformably by a considerable thickness of soft, generally fine-grained sandstone, which in places is indurated into a hard, quartzite-like rock. In their lower part these sandstones are light-coloured, though often stained and banded with ferruginous matter. In their upper part, however, they become very ferruginous, in places passing into an impure ironstone rock, which, by weathering along the joint-planes, assumes the peculiar "cellular" aspect so characteristic of the Northampton Sand of England. As far as I have been able to observe, these sandstones are totally destitute of fossils; and I regard it as probable that, like great portions of the formation which they so greatly resemble in mineral characters, they are of estuarine origin. The rock abounds with spherical cavities, evidently caused by the removal of some foreign matters, probably nodules of iron-pyrites.

The greatest thickness exposed of this sandstone series is about 100 feet, and is seen just north of the Allt-a-ghruan, between the

boat-harbour of Navidale and Dunglass, or Green-Table Point. They are also exposed, but more obscurely, in a small ravine between Wester Garty Burn and Allt-nan-Gabhar (Culgour Burn).

These strata form the highest beds of Secondary age which are exposed *in situ* on the east coast of Scotland.

At Eathie Bay, two miles south of Cromarty, there is a very interesting exposure of the Upper-Oolite rocks. The relations of the Secondary strata at this place to the Silurian and Old Red Sandstone, and the remarkable manner in which they have been rolled and crumpled, and are traversed by pseudo-dykes, has been already described (see pages 126, 127, figs. 9, 10, 11).

These beds have usually been regarded, chiefly on account of their mineralogical character, as of Liassic age; but the details which I shall give concerning their fauna will show conclusively that they exhibit palæontological characters identical with those of the shales, grits, and limestones of Sutherland, which, as we have seen, belong to the Upper-Oolite period.

In lithological characters these beds at Eathie present some slight differences from the contemporary strata to the northward. In the southern of the two patches in Eathie Bay we find beds of hard, very finely laminated shale alternating with bands of argillaceous limestone. The beds of shale often contain nodules of argillaceous limestone and septaria; and these sometimes enclose large and very finely preserved Ammonites. Both the beds of limestone and those of shale, especially the former, are often crowded with fossils. The most abundant forms are:—Ammonites, often of small size, and in prodigious abundance, belonging to the groups of the *Cordati* and *Planulati*; Belemnites, belonging to the remarkably elongated and slender species described by Professor Phillips under the names of *B. spicularis* and *B. obeliscus*; and numerous bivalves, among which *Lima concentrica*, Sow., sp., is specially conspicuous, while *Ostrea Rœmeri*, Quenst., is by no means rare, though generally dwarfed. The abundance of Ammonites, especially of specimens of small size, which occur in clusters containing individuals scarcely exceeding a pin's head in size, is a marked feature. The beds yield also very beautifully preserved fish-remains, saurian bones, and many plants, among which Conifers, Ferns, and Cycads are especially conspicuous. In all these respects we see the close similarity of these beds to the Upper Oolites of Sutherland. On account of the contorted state of the strata at Eathie, it is very difficult to make out their order of succession; but beds of calcareous grit appear on the shore, which apparently underlie the shales and limestones.

The most northern patch at Eathie exhibits strata composed of much coarser materials—namely, sandy black carbonaceous shales, coarse grits, sometimes calcareous and passing into shelly limestones, and sandstones; and these much more nearly resemble the equivalent strata of Sutherland. Marine shells are somewhat rare in them, but they abound in fronds of ferns, wood, &c., and contain also numerous fish-scales.

The presence of a thin carbonaceous band, and the abundance of

plant-remains at Eathie, led to the futile attempts to find coal here which have been already referred to.

Fossils from Eathie (Cromarty), Upper Oolite.

Ichthyosaurus (vertebræ).
Fish-remains (jaws, scales, plates, bones, and teeth).
Aspidorhynchus, sp.
Belemnites spicularis, *Phil.*
—— obeliscus, *Phil.*
—— abbreviatus, *Mill.*
Ammonites mutabilis, *Sow.*
—— ——, var.
—— alternans, *Von Buch.*
—— ——, var.
—— Beaugrandi, *Sauv. et Rig.*
—— flexuosus, *Quenst.*
—— triplicatus, *Sow.*
—— biplex, *Sow.*
Ammonites biplex, *Sow.*, var.
—— Eudoxus, *D'Orb.*
—— Calisto, *D'Orb.*
—— Gravesianus, *D'Orb.*
Turbo, sp.
Avicula, sp.
Lima concentrica, *Sow.*, sp.
——, sp.
Nucula, sp.
Pecten, sp.
Ostrea Rœmeri, *Quenst.*
Conifers (leaves and cones).
Cycads (leaves, buds, stems, &c.).
Ferns (fronds).
Wood.

The marine fossils of the Upper Oolite beds indicate that they agree in age with the middle and lower parts of the English Kimmeridge Clay, the zones of *Ammonites mutabilis* and *A. alternans* of Dr. Waagen.

The general assemblage of fossils presented by these Upper Oolite beds in the north of Scotland more closely resembles that found in some of the French equivalents, in which we have evidence of very similar littoral conditions, than that of the Kimmeridge Clay of England, in which the conditions are somewhat different. The remarkable flora of these beds is of the highest interest, and promises to yield very valuable contributions to our knowledge of the succession of terrestrial plant-life during the Jurassic period, when it shall have been fully studied.

Fragments of the grits and limestones of the Upper Oolite, containing their characteristic fossils, are by no means rare in the Boulder-clay of Elginshire, and have also been detected in Aberdeenshire and Caithness; and masses of blue clay containing the same fossils as the beds at Eathie have been found at Blackpots in Banffshire, Plaidy in Aberdeenshire, and several other localities in the north-east of Scotland.

§ 9. *The Neocomian.*

The question of the former existence of strata of this age in Scotland still remains an open one. Fragments of rock containing the characteristic fossils of the Neocomian have certainly been found enclosed in the Boulder-clay of Elginshire and the adjoining counties; but when we remember a fact which I have pointed out in a previous memoir, namely the great abundance of boulders of rock of this age which are everywhere scattered through the glacial deposits of the North-European area, it becomes us to pause before unhesitatingly referring the fragments in question, which are by no means numerous, to a Scottish origin. On the other hand it must be re-

membered that no portion of the Secondary series in the north of Europe has been almost everywhere so extensively removed by denudation as the Neocomian. From the wide-spread mid-Cretaceous denudation, marking a period of upheaval which preceded that great subsidence during which the *littoral* Upper Greensand and Gault, and the *abysmal* Chalk were deposited, no beds have so greatly suffered as the Neocomian, which were, at the period of that great denudation, the youngest and most recently formed. The proofs of this denudation are familiar to all geologists in the Tourtia of Belgium, the Cambridge Greensand and the Hunstanton Limestone of England; and in a subsequent portion of this memoir I shall have to show what beautiful illustrations of the same great movements are exhibited by the Cretaceous strata of the west coast of Scotland, and in some of the adjoining Hebridean Islands.

While, therefore, we remember the fact that in the North-European district the Neocomian strata, as compared with those of Jurassic age, were originally deposited over more limited areas of sea-bottom, the circumstance of the greater amount of destruction by denudation to which the former, as compared with the latter, have been subjected, should not be lost sight of. The *first* of these considerations, taken in combination with the fact of the comparative rarity of fragments of Neocomian strata in the Scottish drifts, might lead us to decide against the probability of rocks of that age having ever been deposited in the district; if, however, due weight be allowed to the *second* circumstance alluded to, the geologist will hesitate before he accepts as conclusively demonstrated the former absence of the Neocomian beds in a district where even the Jurassic formations have so narrowly, and through such remarkable accidents, escaped total extinction by denudation.

§ 10. *The Upper Cretaceous.*

No such doubt as that which, as we have admitted, still remains concerning the former presence of Neocomian strata in the east of Scotland can be said to exist and to interfere with our adoption of the conclusion that the same area was once covered by strata of the Upper Greensand and Chalk. Although no Upper Cretaceous strata can be detected *in situ* in the north-east of Scotland, yet the vast abundance of the relics of these beds, bearing certificates of their age in their included fossils, which abound in the Boulder-clays of Aberdeenshire, Banffshire, Sutherland, Caithness, and the other counties in the north-east of Scotland, raises the very strongest suspicion that, at a period as recent as the Glacial epoch, great deposits of the Upper Cretaceous still remained unremoved, and supplied numerous boulders to the Till. But when we reflect on what have now been shown to be the relations of the Greensand and Chalk to the other Secondary rocks, alike in Southern Sweden, Western Scotland, the Hebrides, and the north of Ireland, the strong conviction just referred to is converted into something very like certainty.

That in several parts of the county of Aberdeen enormous quan-

tities of chalk flints occur, was first noticed by Dr. Knight, of Marischal College, Aberdeen; the observation, which was confirmed by Dr. Buckland and Mr. (now Sir Charles) Lyell, was published by Sir Roderick Murchison*. In 1841 Mr. Christie pointed out similarly the existence of considerable quantities of chalk flints at Boyndie Bay, Banffshire†. Mr. William Ferguson in 1848–49 showed that over a large tract of Aberdeenshire chalk-flints in great abundance are found in the drift at many points; while at Moreseat, in the parish of Cruden, transported masses of Greensand yielding many fossils also occur‡. Mr. Fergusons's observations were confirmed by Mr. Jamieson§. At the British Association Meeting at Edinburgh in 1850 the late Hugh Miller stated that Mr. Dick, of Thurso, and himself had found numerous boulders of chalk and chalk-flints in the Boulder-clay of Caithness‖. In Sutherland Mr. Joass informs me that chalk flints are by no means uncommon in the Boulder-clay; and I have myself seen examples of them containing characteristic chalk fossils.

In 1857 the late Mr. Salter laid before this Society a very interesting account of the fossils of the Cretaceous boulders of Aberdeenshire¶. In that paper he showed that the masses at Cruden appeared to belong to the Upper Greensand, though the fossils were badly preserved and their determination thereby rendered difficult. I may state that I have found boulders of Greensand containing *Exogyra columba*, Sow., and other characteristic fossils of the Upper Greensand in Elginshire and Banffshire, as well as in Aberdeenshire. The chalk-flints were shown by Mr. Salter to contain a considerable number of characteristic British Upper-Cretaceous fossils, together with some forms hitherto only found in the Chalk of Sweden, and others which were quite new.

The great abundance of the relics of the Upper Cretaceous and their wide distribution in the north of Scotland will probably be accepted by all geologists as affording strong grounds for the suspicion that, when the Boulder-clays were formed, large tracts of Upper Cretaceous strata (Chalk and Greensand) were still in existence in the area, and supplied blocks and fragments to the accumulating Glacial deposits.

When we turn our attention in succession to Scania, Morven in Argyllshire, the Isles of Mull and Inch Kenneth, and the counties of Antrim, Londonderry, and Tyrone, in the north of Ireland, we find the evidences of the former existence of a great mass of Upper Cretaceous strata everywhere overlapping the Jurassic deposits. The Upper Cretaceous beds appear at all these points to have consisted of beds of Greensand at the base, in places passing into conglomerates of peculiar and interesting character; these graduate upwards into,

* Trans. Geol. Soc. 2nd ser. vol. ii. pt. 3, p. 365.

† Edin. Phil. Mag. 1841.

‡ Proc. Phil. Soc. of Glasgow, vol. iii. (1848) p. 33; Lond. Edin. and Dublin Phil. Mag. vol. xxxvii. (1850) p. 430; Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 85.

§ *Ibid.*

‖ Brit. Assoc. Rep. (1850), Proc. of Sections, p. 93.

¶ Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 83.

and are overlain by deposits, often of great thickness and sometimes much altered, of white chalk and flints. It seems reasonable therefore to conclude that a like succession of beds prevailed also in this eastern area of Scotland. The general characters, however, of the Cretaceous rocks of Scotland will be described in the Second Part of this Memoir.

IV. *Phenomena presented by the "Brecciated Beds."*

In the previous pages we have described what may be considered the *normal* aspect presented by the Upper Oolite rocks of Sutherland; this is best illustrated by the sections on the shore in the neighbourhood of Kintradwell and Lothbeg. As we proceed northward from these places, however, we find the same strata assuming new and very remarkable characters, which have deservedly attracted much attention and excited great interest among geologists. I allude to the phenomenon first described by Sir Roderick Murchison under the name of the "Brecciated beds of the Ord."

From Garty northward into Caithness the grits and limestones already described as belonging to the Upper Oolites, while in other respects maintaining their normal characteristics, lithological and palæontological, are found, in certain of their beds, to include numerous masses of foreign rocks of various sizes. The frequency of these included blocks appears to increase as we go northward, till in the exposures about the Ord we find the Upper Oolite strata almost wholly made up of fragments of foreign rocks, some of these being of enormous size, crowded together in the greatest confusion, and cemented by a sandy or calcareous matrix.

The features presented by these remarkable rocks are of the most extraordinary character; and the peculiarity of their appearance is greatly heightened by the strangely disturbed and contorted position of their strata, which has already been described. From Garty northward to beyond the Green-Table Point we find reefs composed of these "brecciated beds," which consist of materials that resist denuding influences in a greater degree, perhaps, than any other of the Secondary rocks; and they are formed by the outcrop of beds which exhibit within short distances the most wonderful variations in dip and strike. Thus the appearance presented at low water is that of a number of massive but ruined walls, composed of irregular blocks of stone, often of enormous size; these vast walls sometimes maintain a perpendicular position, but oftener appear as if slipping from their foundations and inclined in different directions and at various angles; they strike in turn to every point of the compass, and often form curves, sometimes long and sweeping, indicative of the great folds of the beds of which they form the outcrop, and sometimes short, sharp, and repeated, marking the violent contortion of those same beds. Occasionally the appearance of bedding is altogether lost, and the shore appears to be made up of a perfect chaos of blocks of stone of the most various proportions and of every con-

ceivable shape, all cemented together by a concrete, mainly composed of crushed and waterworn Oolitic fossils.

This phenomenon must not be confounded with one which has been already described as occurring at Colyburn and elsewhere—namely, that of the crushing up and recementing of the hard sandstones of the Jurassic series. Not to allude to any other of the numerous points of difference between the rocks in the two cases, there are two features which enable us at once to discriminate the one from the other:—

1. At Colyburn and in the similar cases the included fragments are composed of the same rock as the matrix, and both, where fossiliferous, contain the same organic remains of Secondary age; but in the rocks of the Ord the included masses are certainly foreign to the bed, and they contain Palæozoic fossils, while the investing matrix is of a totally different character, and yields Jurassic fossils.

2. In the former cases the masses of included rock are *always* angular; but in the latter, while they are sometimes perfectly angular, at others they present every degree of attrition, and are not unfrequently converted into perfectly well-rounded pebbles.

No one can observe the remarkable appearances presented by these "brecciated beds" of the Ord, without being struck by the evidences they afford of the action of forces of the most potent character.

Sir Roderick Murchison believed that the phenomenon was to be regarded as the result of the eruption in a solid condition of the granite of the Ord, which, as he supposed, produced, at the same time, both the contortion and brecciated condition of the Oolitic beds. But as we have already seen, Sir Roderick did not recognize, although he seems to have strongly suspected, the foreign nature of the included fragments.

Mr. Hay Cunningham, who does not appear to have studied the Secondary beds of Sutherland with that attention and success which characterized his survey of the Palæozoic rocks of the county, put forward a theory which, merely to state, is to condemn. It is that the "brecciated beds" were formed through the breaking up, by the action of waves on the shore, of certain of the Jurassic beds, and that their redeposition and consolidation in the present inclined positions are due to the same agency.

We have already seen that the contorted and greatly disturbed position of the beds near the Ord is due to their proximity to a great line of fracture, and is part of a series of phenomena presented by the Secondary rocks, whether brecciated or not, wherever they are seen in contact with the Primary. We thus arrive at the conclusion that the contortion and the "brecciation" of the rocks are two totally distinct phenomena; and but little consideration of the facts of the case is required to show that, while the latter must have been produced during the deposition of the strata, the former was the result of forces acting subsequently to their formation.

The first to point out clearly, from the evidence of organic remains, that the masses included in the "brecciated-beds" of the Ord are really of foreign extraction and Palæozoic age was the late

Hugh Miller*; he did not, however, attempt to account for the extraordinary phenomenon presented by them.

Professor Ramsay, who visited this interesting coast in company with Sir Roderick Murchison in 1859, informed me that he had been strongly impressed by the conviction that the phenomena presented by the "brecciated beds" could only be accounted for by calling in the agency of ice-action; and he therefore regarded them as possibly affording evidence of the recurrence in early geological times of glacial periods†. It must be confessed, however, that a careful examination of all the facts exhibits some very startling differences between these deposits of Oolitic age, and ordinary Boulder-clays, or, indeed, any glacial deposits of modern date which have yet been described.

In a subject which, I must confess, appears to present such remarkable difficulties, it seems to me that the interests of science will be better served by laying before this Society the results of a careful study and analysis of all the phenomena of the case, than by the advocacy of any particular theory. I am confirmed in this view when I reflect on the enormous and startling difficulties which the phenomena of an ordinary Boulder-clay presented to the older geologists, and the wild speculations into which they were thereby led, and consider at the same time how these difficulties and the resulting theories have been alike dissipated, by modern researches in physical geography and geology. In the hope and confident expectation, therefore, that the study of the forces now acting on the earth, and the changes produced by them, will, at some future time, afford a complete solution of the remarkable phenomena of the "brecciated beds," as it has already done of so many similar difficulties, I proceed to describe all such details of their nature and mode of occurrence as seem to me to be capable of throwing any light on their mode of origin, and which I have been able to observe during a long and careful study of them.

§ 1. *Order of Succession of the beds.*

The "brecciated beds," which exhibit so many evidences of the action of violent forces in their deposition, alternate with others which quite as strikingly indicate the quietest subsidence of fine sediments from still waters as their condition of accumulation. These latter beds consist of very finely laminated shales, with occasional thin seams of sandstone, sometimes with the surfaces of the beds covered with crushed specimens of *Ammonites* and other marine shells; at other times with the laminæ completely covered with vegetable remains, among which occur many beautiful impressions of ferns, cycads, and conifers, while occasionally the vegetable matter is sufficiently abundant to form thin imperfect coaly or lignite seams. At intervals, in the midst of a great mass of these finely laminated strata, which reach a thickness of many hundreds of feet, we find beds

* The Fossiliferous Deposits of Scotland (1854) p. 373; Testimony of the Rocks (1857) pp. 497–8.

† Phil. Mag. 4th ser. vol. xxix. (1865) p. 290.

sometimes only a foot or two, at other times 50 or more feet in thickness, made up of blocks of foreign rocks, heaped together in the wildest confusion, and cemented by a sandy or calcareous matrix containing Oolitic fossils. One of the best illustrations of the remarkable alternation of these beds of such very different character is afforded by the section at the opening of the romantic gorge of the Allt-gharashtiemore (Gartymore Burn) near the village of Port Gower (see fig. 16).

Occasionally, where the laminated beds have been deposited on the irregular surface formed by the top of one of the "brecciated beds," we see what interference has been produced by the projecting masses of the latter with the usually regular stratification of the former; but as soon as these projections were covered up and masked in clay, the even lamination of the beds is found to be as regular as before.

§ 2. *Age of the "Brecciated beds."*

The investing matrix of the blocks yields many fossils, generally (as is also the case with those of the equivalent strata which are not "brecciated") fragmentary and waterworn. The short and thick Belemnites, and the coarse massive *Ostreæ* have often resisted the forces which have comminuted the other shells. Large masses of waterworn coral, with numerous fragments of wood, also occur in the midst of the heterogeneous assemblage of foreign blocks. The finely laminated beds which alternate with the "brecciated beds," however, yield many fossils in an admirable state of preservation; so that we are at no loss in fixing the age of the beds, which is that of the Upper Oolite. The following fossils are those which most frequently occur in the "brecciated" and associated beds between Garty and the Ord:—

Fossils from the matrix of the "Brecciated beds" of the Ord &c.

Plesiosaurus (vertebræ).
Fish-remains.
Belemnites abbreviatus, *Mill.*
—— (fragments).
Ammonites mutabilis, *Sow.*
—— alternans, *Von Buch.*
—— Eudoxus, *D'Orb.*
—— biplex, *Sow.*
Cerithium, sp.
Turbo, sp.
Nerita?
Lima concentrica, *Sow.*, sp.
Pecten, sp.
Ostrea Rœmeri, *Quenst.*
—— solitaria, *Sow.*
—— expansa, *Sow.*
Rhynchonella Sutherlandi, *Dav.*
Rhynchonella, sp.
Spines of Cidaris and Acrosalenia.
Isastræa oblonga, *Edw. & Haime.*
Leaves (Cycads, Conifers, and Ferns).
Trunks of Conifers and Cycads.

§ 3. *The Matrix of the "Brecciated beds."*

The material which invests and encloses the foreign blocks in these singular strata, varies considerably in character. Usually it is more or less calcareous; but often it is arenaceous, and sometimes argillaceous. Not unfrequently the whole mass of the rock, matrix and included blocks alike, is found traversed by numerous cracks, which are filled with Calc-spar. The great disturbing forces which

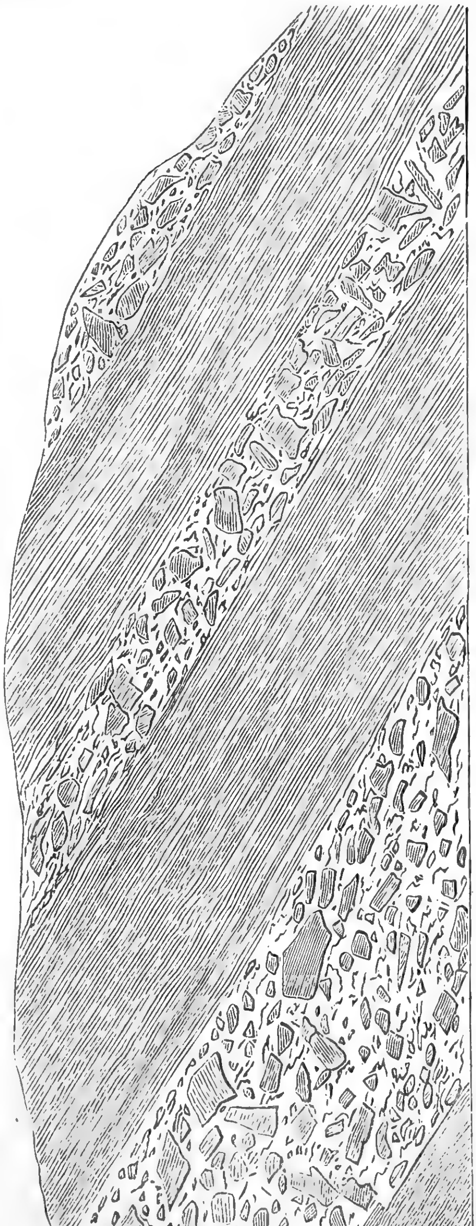


Fig. 16.—*Section at the mouth of the Allt-Gartymore, showing alternation of the "Brecciated beds" (crowded with transported blocks of the Middle Old Red Sandstone), with very finely laminated and lignitiferous sandy shales (Upper Oolite).*

have operated upon these strata since their deposition, and the constant filtration of water through them, at once suggest themselves as the causes of this phenomenon. The calcareous masses of the matrix, which are sometimes sufficiently pure to be burnt for lime, are made up of drifted, waterworn, and comminuted shells, corals, spines of *Cidaris*, &c., with many fragments of wood, and greatly resemble the rock of the Forest-marble. The larger fossils, which remain unbroken, Belemnites, oysters, and corals, usually show signs of having been drifted and waterworn. Among the great extraneous blocks we find numerous trunks of trees completely fossilized; some of these are many feet in length; and with them occur many beautiful stems of Cycads.

§ 4. *The Included Blocks of the "Brecciated beds."*

The careful study of these masses of stone enclosed in the midst of the Upper Oolite strata of Sutherland and Caithness furnishes us with the following details:—

(*a*) *Form.*—Some of the blocks of stone are perfectly *angular*, and on being cleared from the investing matrix exhibit the characters of the surfaces of fracture as clearly and distinctly as if their separation from the parent rock took place but yesterday. These perfectly angular masses constitute the majority of the blocks; but there also exist in great numbers *subangular* fragments of rock, the edges of which exhibit signs of attrition, and which have been evidently subjected, for a limited period, to degrading forces in a stream or on a shore. Lastly, not a few of the fragments, especially among those of smaller size, are completely worn and polished into *pebbles*.

(*b*) *Size.*—The variation of the included blocks in this respect is very remarkable. Sometimes the aspect of a fractured surface of one of the "brecciated beds" is that of an angular gravel, numerous small fragments of foreign rocks being cemented together by sand or shelly detritus. More usually the masses are of much larger size; and, as has been already pointed out, the appearance presented by the beds is that of rough walls, such as are often seen in mountainous districts, composed of angular blocks of the most various size. Occasionally, however, masses are found included in these remarkable "brecciated beds" of such prodigious dimensions as altogether to startle the observer, and bewilder him not a little in seeking for an explanation of the phenomenon. Remarkable examples of this kind are found on the shore opposite to Port Gower, and again between Allt-a-ghruan and Allt-an-aird, south of the Green-Table Point. At the latter locality there is a mass composed of hard light-coloured sandstones, alternating with indurated shales and calcareous flagstones. This mass stands on end, its strata being vertical; and it forms a singular object among the denuded edges of the highly inclined "brecciated beds" in which it lies, its strike being at right angles to theirs, and its dip wholly discordant. The exposed upper edge of this mass measures 20 feet by 10 feet. A little to the south of this is another similar mass, composed of the same materials, the beds of which are also vertical. The continuity

of the mass is not quite so perfectly seen as in the last instance; but it is probably upwards of 40 feet long, and at least 20 feet thick. In the exposed section on the south side of Dunglass (the Green Table) there may be seen, as indicated in the sketch (fig. 5, p. 121), several large included blocks; one of these is about 10 feet long and 4 feet thick.

(*c*) *Position.*—The position of the blocks in the mass is as various as their form and size. In some cases, like those of the great blocks just noticed, the included masses are seen standing on end, with their stratification vertical. In no case does there appear to be any sorting of the materials, which are found heaped together in the wildest confusion, angular and subangular blocks, pebbles, trunks of trees, stems of cycads, masses of coral, shells, shell-detritus, sand and mud.

(*d*) *Markings.*—It may be readily imagined that one of the first channels into which the observations of a student of this singular phenomenon would be directed, in order to detect the cause of transport of these blocks, would be the search for evidence of the action of glacial or floating ice, in the now well-understood and easily recognized polishing, scratching, and grooving which ice-borne rocks usually exhibit. But although innumerable opportunities are afforded for observing the surfaces of the blocks, many of which have evidently not been in the least degree waterworn before being involved in the surrounding and protective matrix, and although I was on the constant look-out for evidence of glacial markings through many weeks during which I studied these beds, yet it must be confessed that *in no single instance was I able to detect a clear and indisputable example of any such markings.*

(*e*) *Material.*—The rocks included as fragments in the "brecciated beds" are somewhat various, consisting principally of calcareous flagstones, often highly micaceous, and exhibiting all the characteristic features of the Caithness Flags of the Middle Old Red Sandstone, with hard sandstones, and indurated, often variegated shales. Occasionally I have found masses which I have been disposed to refer, though with some doubt, to the Silurian strata (altered flagstones) of the district; but blocks of granite or of the conspicuous Old Red conglomerate of the district are, as far as my own observations and those of Sir Roderick Murchison go, altogether absent from the "brecciated beds."

(*f*) *Fossils.*—Hugh Miller was, as already intimated, the first to detect fossils in the included blocks of the "brecciated beds." He records that he found *Osteolepis* and Old-Red-Sandstone fucoids in them; and his testimony, in a matter of this kind, will be admitted to be the most weighty and satisfactory which could possibly be adduced, when we consider the very intimate and exact knowledge which he possessed of the Old Red Sandstone strata of the North of Scotland. His observations I have been able to confirm by the discovery in the blocks in question of very numerous fragments of the Old-Red fishes, preserved in the same manner as is usually the case in the Caithness Flags. Many of these fragments are too small to be

determined; but among them my friend Mr. Joass, who possesses such an intimate acquaintance with the Scottish Old Red Sandstone and its fossils, was able to detect the remains of *Osteolepis* and *Gyroptychius*.

(*g*) *Origin*.—That the great masses of flagstone so abundant in the "brecciated beds" were derived from the Middle Old Red Sandstone or Caithness Flags is thus demonstrated both by their mineral characters and their included fossils. There is every reason to believe that the associated blocks of sandstone and indurated shale came from the same source; indeed, as we have seen, they are found interstratified with the flagstones in some of the great transported masses. We are thus led to conclude that by far the greater number, if not the whole, of these transported blocks were derived from the Caithness Flagstones or Middle Old Red series, the difficulty suggested by Sir Roderick Murchison disappearing, as we have already seen, now that we have demonstrated the enormous faulting and removal of beds by denudation which have taken place in this district subsequent to the deposition of the Jurassic series. The absence of an admixture of foreign blocks from widely different and distant formations is another feature in which the "brecciated beds" differ from those of more modern date, which we now know to have been due to the causes which operated during the Glacial epoch.

§ 5. *General Conclusions as to the Conditions under which the "Brecciated beds" were deposited.*

Refraining, for the reasons already stated, from attempting at the present time to frame any complete theory to account for the formation of these singular beds, I believe we are nevertheless justified, from the consideration of the foregoing facts, in accepting the following general conclusions concerning them:—

1. The whole Jurassic series of Sutherland was deposited in close proximity to land, and large portions of it actually within the estuaries of great rivers. This is as true of the beds of the Upper Oolite as of the other portions of the Jurassic system.

2. The land which bordered the Jurassic sea was not composed of the granites, gneisses, and Old Red conglomerates, which at present constitute so large a portion of Sutherland, but of the calcareous flagstones and associated strata under which the former strata were once deeply buried in this country, and which still form the surface of so large a part of the adjoining county of Caithness.

3. The numerous marine fossils of the Upper Oolites of Sutherland leave no room for doubt that they were accumulated in the sea; but the genera of Mollusca which are most abundant in their fauna, the mineral characters, and the nature of their rock-structure make it equally clear that they were accumulated under decidedly *littoral* conditions.

4. The large and exquisitely preserved flora of these beds indicates that rivers, laden with the spoils of the land, added large and constant contributions to the formation of these same beds.

Localities.	Equivalents.
and the ravine north of Allt-nan-Gabhar.	?
avines near, and reefs on the shore), Loth, Gower, Helmsdale, Navidale, and coast to the Ord (in ravines and reefs on the ιths of ravines at Achrimsdale and Clyne	Kimmeridge Clay (lower part).
ally, Doll, Inverbrora, Strathsteven; reefs osite to Salt-pans; Clayside?	
opposite to Salt-pans; coal-pits; Strath- orking.	Lower Oolites of north-east of Yorkshire?
; Hetherington's pit.	
between Brora and Strathsteven.	
he Secondary strata.	
t of Dunrobin Castle.	Lower part of the Middle Lias (Lias γ, Quenstedt).
of Dunrobin Castle.	Upper part of Lower Lias (Lias β, Quenstedt).
·obin Castle.	Lower part of Lower Lias (Lias α, Quenstedt).
·bin Pier.	Rhætic?
t of Dunrobin, Rhives Wood, Golspie -Wood Park, &c.	New Red Marl?
unrobin and Golspie.	Keuper Sandstones?

TABLE I.—*Illustrating the Succession of the Jurassic Strata in Sutherland.*

Formations.	Nature of the Beds.	Approximate Thickness.	Characteristic Fossils.	Localities.	Equivalents.
UPPER OOLITE.	Light-coloured sandstone passing into ironstones.	feet. 100 +	None.	Allt-a-ghruan, and the ravine north of Allt-nan-Gabhar	?
	Shelly limestones, alternating with clays. Beds of hard grit, alternating with black carbonaceous shales. (These beds are found to become more and more "brecciated" as we go northwards.)	500 ?	*Belemnites abbreviatus*, Mill., *B. obeliscus*, Phil., *B spicularis*, Phil., *Ammonites alternans*, Von Buch, *Am. flexuosus*, Munst., *Am. triplicatus*, Sow., *Am. biplex*, Sow., *Am. autissiodorensis*, Cotteau, *Am. mutabilis*, Sow., *Am. Eudoxus*, D'Orb., *Am. Calisto*, D'Orb., *Cerithium*, sp., *Chemnitzia*, sp., *Nerita*, sp., *Lima concentrica*, Sow., sp., *L. lœviuscula*, Sow., *Avicula expansa*, Phil., var., *Placunopsis*, sp., *Pecten*, sp., *Exogyra nana*, Sow., *Ex. Bruntrutana*, Thurm., *Ostrea Rœmeri*, Quenst., *O. solitaria*, Sow., *O. expansa*, Sow., *Rhynchonella Sutherlandi*, Dav., *Waldheimia humeralis*, Rom., *Terebratula Joassi*, Dav., spines of *Cidaris Aerosalenia*, &c., *Isastrea oblonga*, Edw. & H., *Pisocoturus*, *Gyrodus Cuvieri*, Eg., and other fish-remains, *Bennettites Peachianus*, Carr., and other Cycads, with Ferns, Conifers, &c.	Kintradwell (ravines near, and reefs on the shore), Loth, Garty, Port Gower, Helmsdale, Navidale, and coast northwards to the Ord (in ravines and reefs on the shore), mouths of ravines at Achrimsdale and Clyne Milltown.	Kimmeridge Clay (lower part).
	Coarse sandstones, grits, and conglomerates.	50 ?	Casts of marine shells.	North of Lothbeg River	„
	Beds of sandstone, alternating with black carbonaceous sandy shale, graduating into beds above.	150 +	Plant-remains, *Bel. obeliscus*, Phil., *Am. alternans*, Von Buch, *Am. flexuosus*, Munst., *Lima concentrica*, Sow., &c.	Cliffs and railway-cuttings between Allt-na-cuil and Lothbeg River, cutting at mouth of Lothbeg River	„
	Sandstone often conglomeratic, with casts of shells.	„	*Belemnites obeliscus*, Phil., *Am. Eudoxus*, D'Orb., *Am. mutabilis*, *Am.*, sp., *Am. biplex*, Sow., var., *Avicula expansa*, Phil., var., *Pteroperna*, sp., *Hinnites inæquistriatus*, D'Orb., *Pecten articulatus*, Schloth., *Ostrea Rœmeri*, Quenst., *Rhynchonella pinguis*?, Rom., spines of *Cidaris*, *Aerosalenia*, &c., wood and plant-remains &c.	Allt-na-cuil, stone-pits below and above the cascade	„
	White sandstone, with plant-markings &c.	?	Plant-remains and wood.	Allt-Choille, and cliff to the north	
	White sandstone, with marine shells.	?	*Am. biplex*, Sow., *Trigonia*, sp., &c.	Old stone-pit near Clynish Distillery	
	Beds of bluish-grey argillaceous limestone, with dark blue sandy limestone and clays.	?	*Am. cordatus*, Sow., *Am. excavatus*, Sow., *Am. Lamberti*, Sow., *Am. vertebralis*, Phil., *Am. plicatilis*, Phil., *Nerinæa*, sp., *Goniomya v-scripta*, Sow., *Pholadomya simplex*, Phil., *P. æqualis*, Sow., *Thracia depressa*, Sow., var., *Arca æmula*, Phil., *Trigonia monilifera*, Ag., *T. corallina*, D'Orb., *Cucullæa*, sp., *Modiola bipartita*, Sow., *Pinna lanceolata*, Sow., *Lima lœviuscula*, Sow., *Pecten demissus*, Phil., *P. vimineus*, Sow., *P. vagans*, Sow., *P. subfibrosus*, Sow., *P.*, spec. nov., *Gryphœa dilatata*, Sow., var., *Ostrea gregaria*, Sow., *O. Rœmeri*, Quenst., *Serpula*, Ferns, wood, &c.	Ardassie Point, formerly old pits and trial holes north and west of Braamberry Hill	Coral Rag.
	White unfossiliferous sandstones.	?	None.	Ardassie Point, both sides of Brora Estuary	
	Dark blue pyritous clays and shales.	?	*Belemnites*, sp., *Am. Lamberti*, Sow., *Pecten vimineus*, Sow., *P. vagans*, Sow., *Ostrea gregaria*, Sow., *Cucullæa*, sp., &c.	South of Brora Estuary, old clay-pit at Clynish.	Coral Rag.
	Grey sandy limestone, weathering into rottenstone, and full of shells.	12 ?	*Bel. abbreviatus*, Mill., *Am. Lamberti*, Sow., *Am. vertebralis*, Phil., *Am. excavatus*, Sow., *Aptychus*, sp., *Pholadomya æqualis*, Sow., *Goniomya v-scripta*, Sow., *Thracia depressa*, Sow., var., *Myacites recurvus*, Phil., *Anatina undulata*, Sow., *Isocardia*, sp., *Arca æmula*, Phil., *A. [illegible]*, Rig. et Saur., *Modiola bipartita*, Sow., *Avicula expansa*, Phil., *Pinna lanceolata*, Sow., *Pecten subfibrosus*, Sow., *Pecten*, sp., *Gryphœa dilatata*, Sow., var., *Ostrea gregaria*, Sow., *O. Rœmeri*, Quenst., *Rhynchonella varians*, Sow., *Serpula*, wood and plant-remains.	North of Brora Estuary, old limestone-pit, old limestone-pits and trial holes north and west of Braamberry Hill	„
	White sandstone, conglomeratic in places, with casts of shells.	?	*Gryphœa dilatata*, Sow., var., *Pecten*, sp., *Avicula*, sp., &c.		„
MIDDLE OOLITE.	White sandstones, with lignite-bands &c.	about 200	Plant-remains and wood	Gorge of river Brora, reefs at Brora Point, north of Braamberry Hill, &c.	
	Soft crumbling sandstones, with casts of shells.	?	*Avicula* and other marine shells (badly preserved).	Below village of Brora, in river gorge	
	White sandstone, with lignite-bands &c.	about 100	Plant remains and wood.	Gorge of river Brora, reefs at Brora Point, Braamberry Hill.	
	Sandstone, with casts of shells.	?	*Pecten*, *Myacites*, &c.	Opposite Fascally, in gorge of Brora	
	White sandstones, with thin coaly seams.	60	Plant remains and wood.	West end of gorge of Brora, both sides of river	
	Beds of fine-grained marine sandstone, passing into a kind of white chert, and abounding with beautiful casts of fossils.	25	*Bel. sulcatus*, Mill., *Am. perarmatus*, Sow. (varieties), *Am. Sutherlandiæ*, Sow., *Am. cordatus*, Sow. (varieties), *Am. Achilles*, D'Orb., *Am. lunula*, Ziet., *Am. anceps ollus*, Quenst., &c., *Aptychus*, sp., *Pleurotomaria*, sp., *Trochus*, sp., *Turbo*, sp., *Chemnitzia*, sp., *Goniomya v-scripta*, Sow., *Myacites*, sp., *Pholadomya*, sp., *Lucina*, sp., *Trigonia Joassi*, Lyc., *Modiola bipartita*, Sow., *Lima lœviuscula*, Sow., *Lima pectiniformis*, Schloth., *Pinna lanceolata*, Sow., *Avicula [illegible]*, Sow., *Pecten fibrosus*, Sow., *P. vimineus*, Sow., *P. inæquicostatus*, Phil., *P. vagans*, Sow., &c., *Placunopsis*, sp., *Ostrea Rœmeri*, Quenst., *Gryphœa dilatata*, Sow., *Terebratula bisuffarcinata*, Schloth., *Waldheimia*, sp., *Bucklandia Milleriana*, Carr., *Yatesia crassa*, Carr., *Y. Joassiana*, Carr., other Cycads, *Equisetites*, Ferns, coniferous wood, &c., large masses of wood perforated by mollusks &c., and with adhering shells.	Both sides of Brora at Fascally, stone-quarries at Hare Hill and Braamberry Hill, pits in deer-forest above Dunrobin?, pits about Uppat and Strathsteven?	Lower Calcareous Grit
	Grey sandy clays, with nodular limestone. Sandy shales, with few fossils. Bituminous and pyritous shales, with septaria.	75 80 55	*Belemnites sulcatus*, Mill., &c. *Belemnites*. *Belemnites*, very abundant (most of the fossils destroyed by the decomposition of pyrites).	Cliff above coal pit at Fascally, reefs at Brora. Coal shafts and borings, and reefs on shore at Brora, cliff north of river Brora.	Oxford Clay, in part ("Ornaten-Thon" Quenst.)
	Hard sandy shales, passing into argillaceous sandstone.	25	*Bel. Owenii*, Pratt, *Bel. hastatus*, De Blainv., *Ammonites ornatus*, Schloth., *Am. Jason*, Rein., *Am. Duncani*, Sow., *Am. Bakeriæ*, Sow., *Am. Kœnigi*, Sow., *Am. athleta*, Phil., *Chemnitzia Heddingtonensis*, Sow., *Cerithium muricatum*, Sow., *[illegible]*, Phil., *Myacites*, sp., *Thracia*, sp., *Isocardia tenera*, Sow., *Corbula Oxfordensis*, D'Orb., *Nucula*, sp., *Cucullæa*, sp., *Lucina*, sp., *Avicula*, sp., *Pecten*, sp., *Gryphœa dilatata*, Sow., wood in form of jet.	Bluff on north side of River Brora, shafts and borings of coal pits, reefs near Brora Point, Clayside	
	Black, finely laminated shales, with bands of septaria, and beds made up of crushed shells.	70	At the base numerous small bivalves, *Nucula nuda*, Phil., *Pecten*, sp., with *Ammonites Gowerianus*, Sow., *Am. Calloviensis*, Sow., and *Belemnites*.	Reefs on shore near Brora, coal pits	Oxford Clay, in part and Kelloway Rock
	Calcareous sandstone, passing into a limestone in its upper part ("Roof-bed").	5	*Bel. Owenii*, Pratt (varieties), *Am. Gowerianus*, Sow., *Am. sublævis*, Sow., *Am. Kœnigi*, Sow., *Rostellaria composita*, Sow., *Alaria*, sp., *Cerithium muricatum*, Sow., sp., *Actæon retusus*, Phil., *Buccinum*?, *Pholadomya Murchisoni*, Sow., *P.* [illegible], *Myacites recurvus*, Phil., *M.* [illegible]*formis*, Phil., *Gresslya peregrina*, Phil., *Goniomya v-scripta*, Sow., *Cardium striatulum*?, Sow., *C.* [illegible], Phil., *Isocardia tenera*, Sow., *Nucula*, Phil., [illegible] *Gervillia aviculoides*, Sow., *Pecten lens*, Sow., *P. demissus*, Phil., *Gryphœa dilatata*, Sow., *Ostrea Marshii*, Sow., &c., wood.	Coal pits of Fascally, Doll, and Inverbrora, reefs on shore opposite to Salt pans, cliff at Strathsteven (coal-works).	Kelloway Rock.
LOWER OOLITE.	Main seam of coal.	3 feet 8 inches	*Equisetites columnare*, Brongn.	Coal-pits, Fascally, Doll, Inverbrora, Strathsteven, reefs on shore opposite to Salt pans, Clayside?	
	Black shales, with thin coal-seams, shelly bands, bone-bands, &c.	feet. 20	*Unio*, *Cyrena*, *Perna*, *Ostrea*, *Cypris*, &c.; scales and teeth of *Lepidotus*, *Semionotus*, *Pholidophorus*, *Hybodus*, *Acrodus*, &c., *Equisetites*, and other plant-remains.	Reefs on shore opposite to Salt-pans, coal-pits, Strathsteven coal working	Lower Oolites of north-east of Yorkshire?
	Variegated shales and impure fire-clays; thin coal-seams, bands and nodules of argillaceous limestone.	96	*Cyrena*, *Ostrea* (dwarfed), &c.	Reefs on shore, Hetherington's pit.	
	White sandstones and shales.	110 +	Occasional *Cyrena*, bands with casts of marine shells, *Myacites*, *Trigonia*, &c.	Reefs and cliffs between Brora and Strathsteven	

The relation of the above strata to the Lias is nowhere seen in the county of Sutherland, owing to the great transverse faults which have affected the Secondary strata.

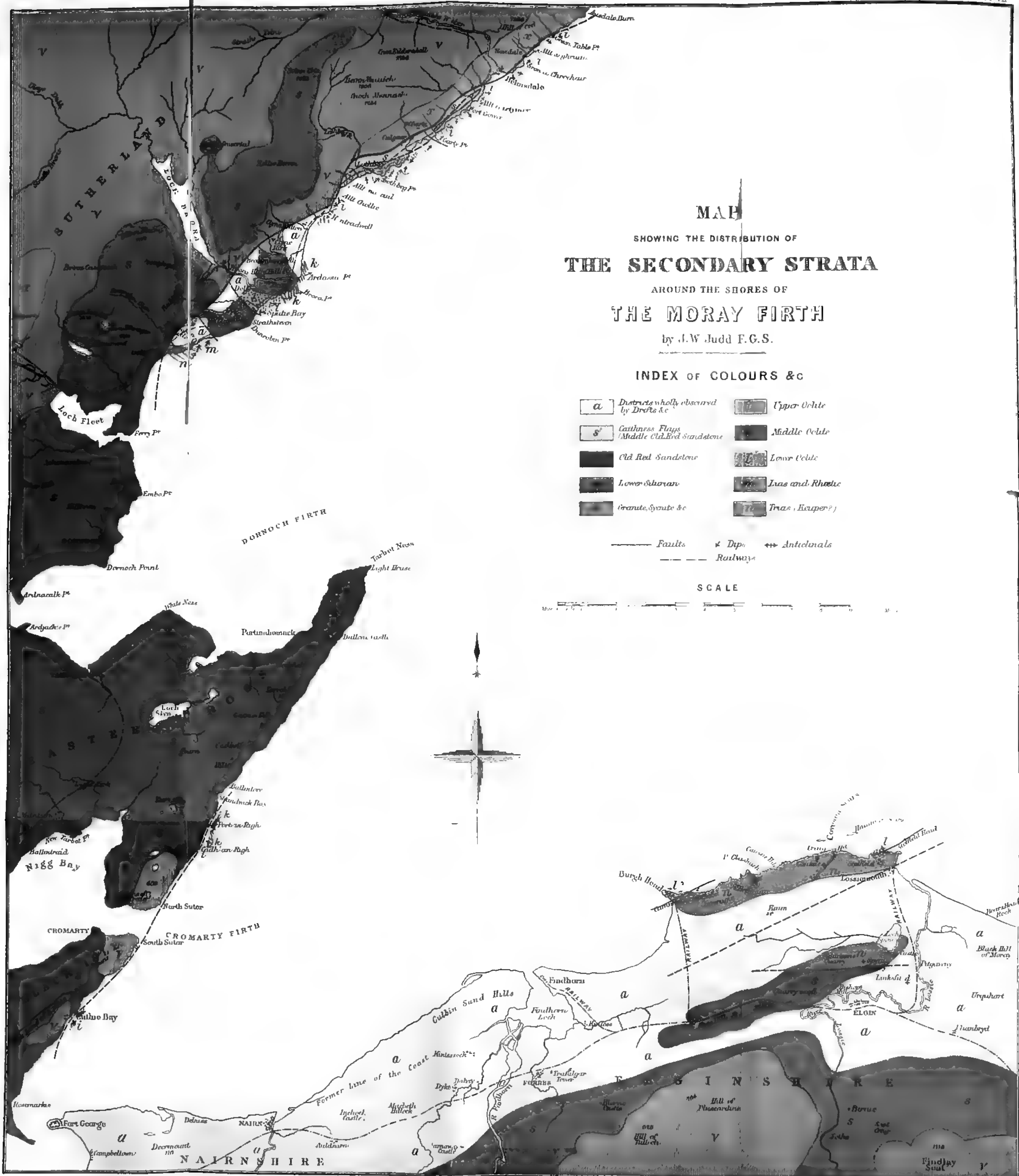
Formations.	Nature of the Beds.	Approximate Thickness.	Characteristic Fossils.	Localities.	Equivalents.
LIAS.	Beds of dark blue, highly micaceous clay, with numerous septaria.	80 +	*Ammonites brevispina*, Sow., *Am. Jamesoni*, Sow., *Am. oxynotus*, Quenst., var., *Bel. acutus*, Mill., *Bel. clavatus*, Schloth., *Cardinia attenuata*, Sow., sp., *C. lanceolata*, Stutch., *Hippopodium ponderosum*, Sow., *Pholadomya decorata*, Ag., *Pleuromya unioides*, Rom., sp., *Unicardium cardioides*, Phil., sp., *Cardium truncatum*, Sow., *Lima pectinoides*, Sow., *Cucullæa Munsteri*, Goldf., *Modiola numismalis*, Opp., *Pinna folium*, Y. & B., *Pecten lunaris*, Nyst, *P. sublævis*, Phil., *Plicatula spinosa*, Sow., *Gryphœa cymbium*, Lam., var., *G. obliqua*, Sow., *Terebratula punctata*, Sow., *Rhynchonella amalthei*, Quenst., *Pentacrinus moniliferus*, Quenst.	Reefs north-east of Dunrobin Castle.	Lower part of the Middle Lias (Lias γ, Quenstedt).
	Beds of impure limestone, alternating with shale, the former full of shells.	100	*Am. oxynotus*, Quenst., *Am. capricornus*, D'Orb., *Bel. acutus*, Mill., *Pholadomya ambigua*, Sow., *Tancredia*, sp., *Hippopodium*, sp., *Cardinia hybrida*, Sow., sp., *C. lanceolata*, Stutch., sp., *Pleuromya unioides*, Rom., sp., *Unicardium cardioides*, Phil., sp., *Modiola*, spec. nov., *Pecten sublævis*, Phil., *P. tumidus*, Ziet., *P. liasinus*, Nyst; *P. textorius*, Schloth., *Pinna Hartmanni*, Ziet., *Lima pectinoides*, Sow., *L. punctata*, Sow.; *L. Koninckana*?, Chap. et Dew., *Ostrea*?, sp.; *Gryphœa obliqua*, Sow., *Rhynchonella tetrahedra*, Sow., *R. variabilis*, var. *triplicata*, Phil., wood.	Reefs north-east of Dunrobin Castle	Upper part of Lower Lias (Lias β, Quenstedt).
	Beds of sandstone, with bands containing vertical plant-markings. Beds of sandstone and shale, with coal-seams.	? about 400	Casts of marine shells (*Pecten* &c.) in upper part. Plant-remains.	Reefs below Dunrobin Castle	Lower part of Lower Lias (Lias α, Quenstedt).
	Beds of sandstone and conglomerate.	?	None?	Reefs near Dunrobin Pier	Rhætic?
TRIAS.	Concretionary cream-coloured limestones, passing into chert.	10-20 ?	None.	Reefs south-west of Dunrobin, Rhives Wood, Golspie Burn, Quarry Wood Park, &c.	New Red Marl?
	Beds of yellow and light-coloured sandstone.	40-50 seen.	None.	Reefs between Dunrobin and Golspie.	Keuper Sandstones?

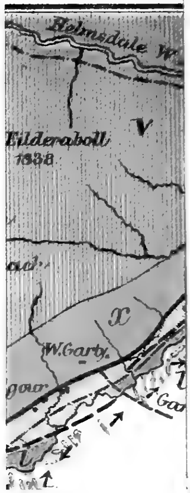
[*To follow* Table I.]

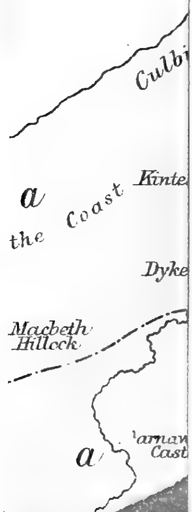
		seen *in situ* in other counties.	Transported masses in the drifts, &c.
CRETACEOUS.	Ch		Masses of chalk-flints in Aberdeen, Banff, Sutherland, &c.
	Up a		Fragments of greensand with fossils (Elginshire, Aberdeenshire, &c.).
	Ne		?Elginshire, Aberdeenshire (Urquhart, Plaidy, &c.).
			Boulders, Lossiemouth (Elginsh.) &c.
JURASSIC.	Up	reen-Table Point (Caithness).	,, Elginshire, Banffsh. (Black-pots, &c.).
		(Cromarty).	,, Caithness, Morayshire, &c.
			,, Elginshire.
			?
			?
		n-Righ (Ross).	,, Elginshire (Urquhart &c.), rolled fragments on shore, &c.
			,, Elginshire, Banff, &c.
	Mi		,, Urquhart (Elginshire).
			? ?
			,, Elginshire.
		-an-Righ (Ross).	,, Elginshire, and in rolled fragments on shore.
		,,	,, Elginshire, &c.
		,,	,, Loch Spynie (Elginsh.), &c.
		,,	? ?
		,,	? ?
	Lo	eld and Burghead? (Elginsh.).	,, Elginshire, &c.
		?	,, ,,
	Mi		Fine-grained micaceous sandstone, Lhanbryd, Loch Spynie, and other localities in Elginshire, &c.
			Boulders, Loch Spynie &c. (Elginsh.).
	Lo		,, Kaim, Inverugie, &c. (Elg.).
			? ?
TRIAS.	Rh		? ?
	Ke	rty rock of Stotfield," Elginsh.	Drifts of Elginshire, on shore, &c.
		tiliferous Sandstones," ,,	? ?

TABLE II.—*Comparative View of the Secondary Rocks of the East Coast of Scotland.*

	Formations.	Groups.	Strata seen *in situ* in Sutherland.	Nature.	Approximate Thickness in feet.	Strata seen *in situ* in other counties.	Transported masses in the drifts, &c.
CRETACEOUS.	CHALK.						Masses of chalk-flints in Aberdeen, Banff, Sutherland, &c.
	UPPER GREENSAND and GAULT.						Fragments of greensand with fossils (Elginshire, Aberdeenshire, &c.).
	NEOCOMIAN.						?Elginshire, Aberdeenshire (Urquhart, Plaidy, &c.).
			z. Light-coloured and ferruginous sandstones passing into impure iron-stones.	Estuarine.	100+		Boulders, Lossiemouth (Elginsh.) &c.
JURASSIC.	UPPER OOLITE.	Zones of *Am. mutabilis* and *Am. alternans* of Waagen (Kimmeridge Clay, lower part).	*y.* Coarse shelly limestones. } "Brecciated beds."	Marine.	500+	N. of Green-Table Point (Caithness).	,, Elginshire, Banffsh. (Black-pots, &c.).
			x. Finely laminated carbonaceous shales with shelly grits. } "Brecciated beds."	Marine and Estuarine.		Eathie (Cromarty).	,, Caithness, Morayshire, &c.
			w. Coarse sandstones, grits, and conglomerates (casts of marine shells).	Marine.	50?		,, Elginshire.
			v. Coarse sandstones with plant-remains, coaly seams, &c.	Estuarine.	150+		?
			u. Sandstones with marine shells.	Marine.	?		?
		Coralline Oolite.	*t.* Sandy and argillaceous limestones, clays, and sandstones.	Marine, &c.	200?	Port-an-Righ (Ross).	,, Elginshire (Urquhart &c.), rolled fragments on shore, &c.
	MIDDLE OOLITE.	,, ,,	*s.* A great mass of coarse sandstones with coaly seams (several marine bands).	Estuarine.	400		,, Elginshire, Banff, &c.
		Zone of *Am. perarmatus*, Wright (Lower Calcareous Grit).	*r.* Marine sandstones, fine-grained, graduating into beds below.	Marine.	25		,, Urquhart (Elginshire).
			q. Sandy shales, with few fossils.	Marine.	150		? ?
		Zone of *Am. Jason*, Wright (Oxford Clay, part).	*p.* Blue pyritous and laminated shales passing into sandstones.	Marine.	80		,, Elginshire.
			o. Black laminated shales with septaria and shelly bands.	Marine.	70	Cadh'-an-Righ (Ross).	,, Elginshire, and in rolled fragments on shore.
		Zone of *Am. calloviensis*, Wright (Kelloway Rock).	*n.* Calcareous sandstone crowded with fossils ("Roof-bed").	Marine.	5	,,	,, Elginshire, &c.
	LOWER OOLITE (and UPPER LIAS?).	Great Oolite?	*m.* *Coal*, with band of pyrites in its midst.	Estuarine.	$3\frac{1}{2}$	,,	,, Loch Spynie (Elginsh.), &c.
			l. Variegated estuarine clays, bands of estuarine shells, impure *coals*, &c.	Estuarine.	110	,,	? ?
			k. White sandstones with subordinate beds of shale.	Estuarine.	100+	,,	? ?
			j. Sandstone with casts of marine fossils.	Marine.	?	Stotfield and Burghead? (Elginsh.).	,, Elginshire, &c.
			i. Sandstones and shales.	Estuarine.	? very great.	,, ?	,, ,,
	MIDDLE LIAS.		[Interval not represented in the Sutherland sections.]				Fine-grained micaceous sandstone, Lhanbryd, Loch Spynie, and other localities in Elginshire, &c.
	LOWER LIAS.	Zone of *Am. Jamesoni*, Oppel.	*f.* Thick mass of blue micaceous clays with many fossils.	Marine.	80+		Boulders, Loch Spynie &c. (Elginsh.).
		Zones of *Am. raricostatus* and *Am. oxynotus*, Oppel.	*e.* Sandy limestones alternating with blue clays; many fossils.	Marine.	100		,, Kaim, Inverugie, &c. (Elg.).
			d. Alternations of sandstone and shale, with two (or more) thin seams of coal (no marine fossils).	Estuarine.	400		? ?
TRIAS.	RHÆTIC?	Zone of *Avicula contorta*, Wright.	*c.* Thick series of conglomerates, sandstones, and grits, sometimes calcareous (contains pebbles of *b* and *a*).	Marine?	50+		? ?
	KEUPER?		*b.* Concretionary, cream-coloured limestones passing into chert &c.	Lacustrine?	10 to 20?	"Cherty rock of Stotfield," Elginsh.	Drifts of Elginshire, on shore, &c.
			a. Beds of yellow and light-coloured sandstone.		50+	"Reptiliferous Sandstones," ,,	? ?


MAP
SHOWING THE DISTRIBUTION OF
THE SECONDARY STRATA
AROUND THE SHORES OF
THE MORAY FIRTH
by J.W Judd F.G.S.
INDEX OF COLOURS &c
Districts wholly obscured by Drifts &c
Caithness Flags (Middle Old Red Sandstone
Old Red Sandstone
Lower Silurian
Granite, Syenite &c
Upper Oolite
Middle Oolite
Lower Oolite
Lias and Rhætic
Trias (Keuper?)
Faults
Dips
Anticlinals
Railways
SCALE
SUTHERLAND
Loch Fleet
Ferry Pt
Embo Pt
Dornoch Point
DORNOCH FIRTH
Tarbet Ness
Light House
Portmahomack
Loch Eye
New Tarbet Pt
Nigg Bay
North Sutor
CROMARTY
CROMARTY FIRTH
South Sutor
Rosemarkie
Fort George
Campbeltown
NAIRN
NAIRNSHIRE
Culbin Sand Hills
Former line of the Coast
Findhorn
FORRES
Burgh Head
Lossiemouth
ELGIN
Covesea Skerries
Helmsdale
Brora Pt
Dunrobin Pt
Spinningdale
Hill of Pluscarden


W.Garty.


the Coast
Macbeth Hillock

5. The alternation of the "brecciated beds" with the finely laminated and quietly deposited strata, and the confused arrangement of the blocks in the latter, their admixture with trunks of trees, stems of cycads, and other plant-remains, seem to indicate that the quiet deposition of the semi-estuarine beds was interrupted by the occasional occurrence, in the rivers just alluded to, of floods of the most violent character. These appear to have swept angular masses, just separated from their parent rock by frosts or landslips, subangular masses which had lain for a time in the course of the streams, and the rounded pebbles of the river-beds, along with trunks of trees torn from their banks, all in wild confusion out to sea, where they were mingled with the sea-derived materials of the shell-banks and shoals.

6. The continuity which is preserved in masses of enormous dimensions composed of a number of strata, seems to suggest the action of some agency in their transport beyond that of floods; and the only one which we are at present acquainted with capable of thus buoying up these enormous masses unbroken to their destination, appears to be *ice*. Possibly, too, it will be difficult to account for the occurrence of floods of such extraordinary violence as those we have shown must have occurred, except upon the supposition that the country was subject to those vicissitudes incident to the presence of glaciers in neighbouring mountains.

7. The total absence of glacial polishing and striation from the surfaces of the transported blocks, and the abundance of a splendid flora abounding in cycads, ferns, and large trees on the adjoining land, to say nothing of the characters of the abundant marine fauna, entirely preclude the idea that these masses were actually heaped together by glaciers which came down to the sea-level.

8. The local character of these blocks, and the absence of far-travelled boulders, alike indicate that these accumulations could not have been formed by the stranding and melting of icebergs.

Here then we pause, in the expectation that future researches in the physical geography of some as yet little-studied region may demonstrate the existence, in the same combination, of those conditions which we have shown must have been present during the deposition of the wonderful "brecciated beds" of the Ord.

EXPLANATION OF THE MAP. PLATE VII.

As the basis of this map the Admiralty Chart of the Moray Firth, on a scale of two geographical miles to an inch, has been employed, the Ordnance Survey of this part of Scotland not being yet completed. In drawing the boundaries of the Palæozoic rocks, I have, in the main, followed the older maps of Macculloch, Hay-Cunningham, and Martin, adopting, however, many corrections from more recent authorities, such as Prof. Nicol, Murchison and Geikie, and the Rev. J. M. Joass. The geological lines for the Mesozoic formations I have myself supplied. No attempt has been made to represent, on the southern side of the Firth, the complicated relations of the Primary and Secondary strata which have been brought about by the great faults; even if it were practicable to trace these relations with any approach to certainty in a district so covered with drift-deposits, it would be impossible to exhibit them on a scale so small as that of this map.

NOTE *on some* BRACHIOPODA *collected by* Mr. JUDD *from the* JURASSIC DEPOSITS *of the* EAST COAST *of* SCOTLAND. By THOMAS DAVIDSON, Esq., F.R.S., F.G.S.*

[PLATE VIII.]

AMONG the Brachiopoda collected by Mr. Judd from the Jurassic deposits of the north of Scotland we find four species particularly worthy of notice. Two are, as far as I am aware, quite new, and two new to Great Britain. Three of the four have likewise been obtained from the Upper Oolite or equivalent of the Kimmeridge Clay; and this is the more remarkable since the species of Brachiopoda recorded from that formation are comparatively few.

RHYNCHONELLA SUTHERLANDI, n. sp. Pl. VIII. figs. 1, 2.

Shell transversely oval, wider than long, greatest breadth about the middle. Ventral valve convex; sinus wide, moderately deep; foramen rather small, placed under the incurved extremity of the beak, surrounded and slightly separated from the hinge-line by a deltidium of small dimensions. Dorsal valve deeper and more convex than the opposite one, sometimes very gibbous, and divided into three portions, the central one being formed by a wide mesial fold. Surface of each valve marked with from sixteen to thirty large angular ribs, of which from six to twelve occupy the fold, five to thirteen the sinus. Proportions very variable. A large specimen measured $2\frac{2}{8}$ inches in length by $2\frac{6}{8}$ inches in breadth.

Obs. This is one of the largest species of the genus with which I am acquainted, having been exceeded in size, as far as I am aware, only by the *R. multicarinata*, Lam., = *Terebratula peregrina*, v. Buch, and the *R. inconstans speciosa* of Münster. In external shape and character it most nearly approaches the smaller *R. Renauxiana*, D'Orb., from the Upper Neocomian of the south of France. It varies likewise very much in the number and strength of its ribs; but this is a feature common to almost every species of the genus.

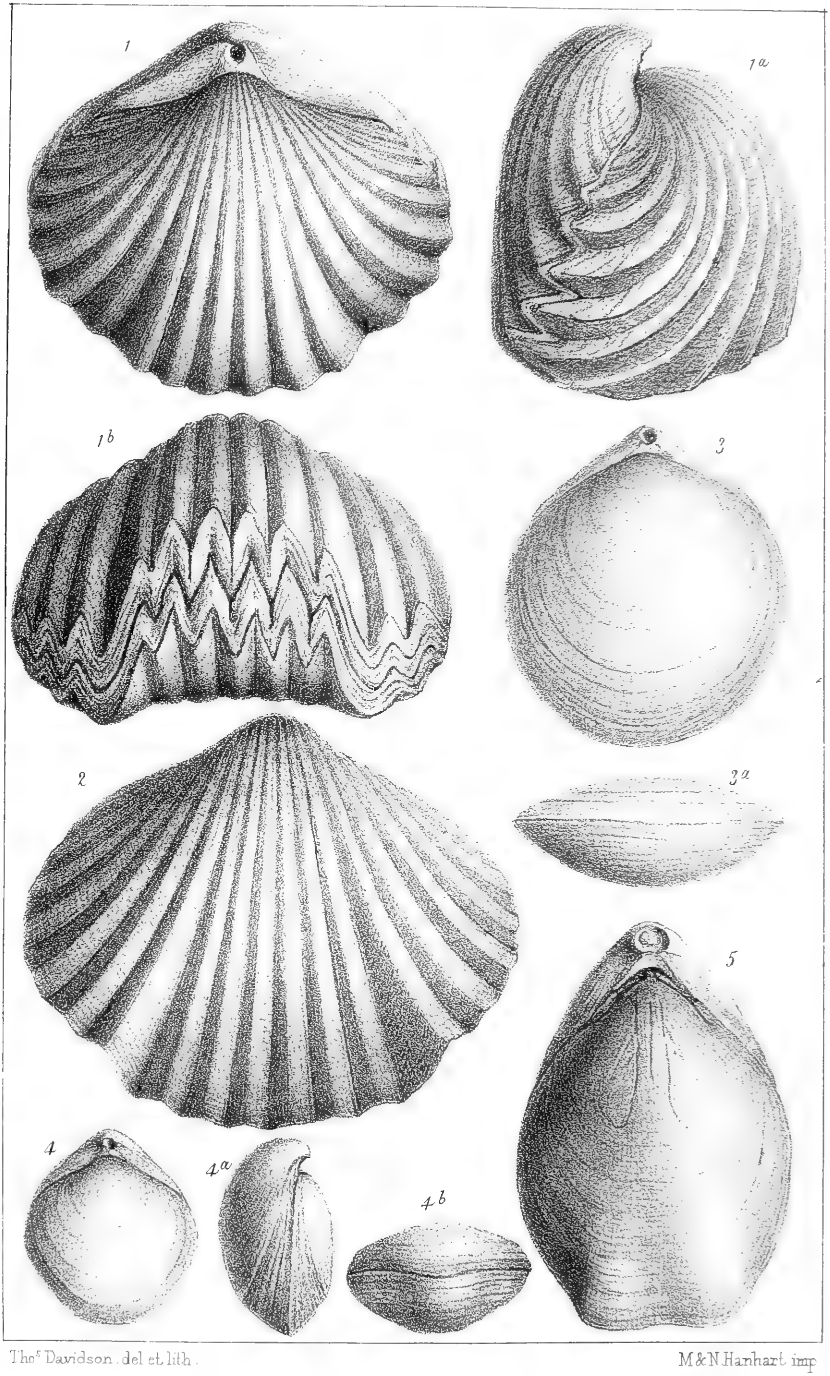
R. Sutherlandi appears to be a common shell in the grey Upper Oolite limestone at Garty, in Sutherland, the specimens figured having been communicated by the Rev. J. M. Joass from the Dunrobin Museum. We have named it after His Grace the Duke of Sutherland, in humble appreciation of the service he is rendering to science by the formation of a local museum at Dunrobin.

TEREBRATULA JOASSI, n. sp. Pl. VIII. figs. 3, 3*a*.

Shell longitudinally oval, broadest anteriorly, slightly tapering at the beak. Valves very moderately convex, without fold or sinus; beak small, incurved and truncated by a circular foramen, slightly separated from the hinge-line by a deltidium in one piece. Dorsal valve sometimes very much flattened. Surface smooth, marked by concentric lines of growth. Length $1\frac{6}{8}$ inch, breadth $1\frac{1}{2}$ inch, depth $\frac{5}{8}$.

Obs. The species which this shell most nearly approaches is the

* Read March 12, 1873.



Thos Davidson. del et lith.

M&N Hanhart imp

SCOTTISH JURASSIC BRACHIOPODA.

T. ovoides, Sow.,=*T. rex*, Lankester; but it differs from it in the absence of any mesial depression in the dorsal valve, and carination in the ventral one. It was found by Mr. Judd in the Upper Oolite of Garty, Sutherland; and I have much pleasure in naming it after the Rev. J. M. Joass, who has devoted so much attention to the Jurassic formations of that part of Scotland.

TEREBRATULA (or WALDHEIMIA) HUMERALIS, Rœmer. Pl. VIII. figs. 4*a*, 4*b*.

Specimens agreeing in every particular with the *T. humeralis*, Rœmer (of which an excellent description and figures will be found at p. 414 of the 'Description Géologique et Paléontologique des étages Jurassiques de la Haute Marne,' by Messrs. P. de Loriol and E. Royer), appear to be common in the Upper Oolite of Garty, in Sutherlandshire. In France, according to the palæontologists above named, it occurs in the "Calcaire à Astartes" or upper portion of the Coralline Oolite, a zone underlying the Kimmeridge. It had not been hitherto recorded as a British species.

TEREBRATULA BISUFFARCINATA, Schlotheim. Pl. VIII. fig. 5.

Internal casts of this species are extremely abundant in the Coralline Oolite, or zone of *Ammonites perarmatus*, Lower Calcareous Grit of Braamberry Hill in Sutherlandshire. In 1862 I mistook it for *T. perovalis*, which some examples of Schlotheim's species much resemble; but while comparing the numerous Scottish specimens collected by Mr. Judd with some typical forms of *T. bisuffarcinata* from the Korallen-Kalk of Muggendorf, recently sent to me by Dr. Sandberger, the identity of the Braamberry-Hill specimens became apparent.

In the same locality Mr. Judd obtained two internal casts, about an inch in length, of a well-characterized *Waldheimia*; but a further search for more specimens will be needed before attempting its specific identification.

Internal casts of a *Rhynchonella*, much approaching *R. pinguis*, Rœmer, have also been found in a light-yellow sandstone, slightly tinged with red, belonging to the Upper Oolite of Allt-na-Cuil, in Sutherlandshire; but as the Scottish Liassic and Oolitic Brachiopoda will, I hope, be fully treated in the forthcoming supplement to my monograph, it may be preferable to reserve all further details for that publication.

EXPLANATION OF PLATE VIII.

Figs. 1, 2.—*Rhynchonella Sutherlandi*, sp. n. Upper Oolite, Garty.
Figs. 3, 3*a*.—*Terebratula Jaossi*, sp. n. Upper Oolite, Garty.
Figs. 4, 4*b*.—*Terebratula humeralis*, Rœm. Upper Oolite, Garty.
Fig. 5.—*Terebratula bisuffarcinata*, Schl. Lower Calcareous Grit, Braamberry Hill.

January 22, 1873.

Charles Fox Strangways, Esq., of the Geological Survey of England and Wales, 45 East Mount Road, York; Alexander Irving, Esq., High School, Nottingham; Thomas Lidney Dickinson, Esq., of Newbold, near Chesterfield; William Bath Kemshead, M.A., Ph.D., F.R.A.S., Lecturer on Chemistry and Physical Science, Dulwich College, Hanover Villa, Thurlow Park Road, Dulwich, S.E.; J. M'Murtrie, Esq, of the Radstock Collieries, Somersetshire; and John Dawes, Jun., Esq., Manor Colliery, Hales Owen, near Birmingham, were elected Fellows of the Society.

The following communication was read:—

On the Glaciation *of* Ireland.

By J. F. Campbell, Esq., F.G.S.

The following notes are founded chiefly upon observations made while travelling about Ireland in 1863 and 1872, and at intermediate dates.

A subject may be treated in two ways. If the whole of a story is known it may be told historically, from the beginning; but if a lesson has to be learned, it is best to work back towards the unknown beginning. A great deal has yet to be learned about glaciation; so I begin at the end.

I. *Iceland and Ireland*, in different latitudes, are about the same size. In one island are ice systems, in the other none. Some Icelandic glaciers are wide as an Irish province; and others would cover Irish counties. In Ireland lakes seldom freeze, and snow melts off the highest tops early in spring. But Ireland is glaciated.

II. *Ireland*.—The meridian 8° west cuts Ireland nearly in half. In the north it passes near Arrigle, the highest hill in Donegal; in the south it passes near Cork. But the figure of the island is not square to meridians. A line drawn through Dursey Island and Rathlin, S.W. and N.E. or thereby, passes through the long axis of a diamond whose shorter axis runs from the Tuskar Rock in Wexford north-westwards to near Achill Island in Mayo. The configuration of surface within this area has relation generally to two main lines, N.E. and N.W. In Donegal, Mayo, Galway, Kerry, and Cork the largest mountain-ridges and hollows trend N.E. The course of the Shannon, the largest river in Ireland, is from the east of north. Most of the largest sea-lochs in Ireland trend N.E. and S.W. Passes in the Mourne Mountains (in Down), Carlingford Lough on the east coast, and the valley of the Erne on the west trend N.W. and S.E. The hollows which contain the river Ban and Loch Neagh and the valley of the Waterford river trend north and south. But for one great hollow running north and south a great number run N.W., and a greater number N.E. It is easily seen on any good map of Ireland that roads, canals, railways, rivers, lakes, harbours, and marshes, which occupy hollows and avoid hills, have

a general N.E. and N.W. extension, and cross meridians from 6° to 10° west, diagonally between latitudes 51° and 56° north. There must be some reason for the shape of the coast and surface of this part of the earth's solid crust.

III. *Under Water.*—Beyond high-water mark in harbours the sea now packs layers of mud and shingle in rocky hollows; but near the coast, and far out at sea, peaks of rock stand up in the midst of undulating plains of drift, of which the charts give the form in fathoms below the plane of the water. The limit of 600 feet is far from shore. The sea-bottom about Ireland is an undulating plain with rocky hills in it, very like plains on shore.

IV. *On Shore.*—The greater part of the area of Ireland consists of low undulating rock-surfaces, covered with Boulder-clay, with water drifts of sand and gravel, with soil and peat-bogs. Amidst this cover of loose materials stand groups of bare rocky mountains, and isolated hills, knolls, and hillocks of solid rock. The highest point in Ireland is 3404 feet above the sea-level, near Killarney, in the S.W. So far as my own observations and my reading enable me to form an opinion, the present shape of all the rock-surfaces in Ireland, from the highest tops to the sea-level, is the result of wearing and waste; and the shape of the low lands is the result of packing fragments, broken, crushed, ground, or worn off solid rocks. Some great denuding engines must have worked on this region.

As the drift is commonly "glacial" next to the rock, and as most of the rock-surfaces in Ireland still are "glaciated" where they have been protected from water and weather, I attribute the present shape of the surface of Ireland chiefly to glacial action during a geological period later than the formation of the Antrim chalk.

V. *Denudation* *.—That large masses of solid rock have been

* On the day before this paper was read, Professor Ramsay was kind enough to lend me a map marked with the broad arrow of the Ordnance Survey, and thus described on the face of it:—

"Map of Ireland to accompany the report of the Railway Commissioners, 1838, &c., &c.; engraved under the direction of Lieut. Larcom, Royal Engineers, May 1837 (in MS.). *Coloured to represent portions of Ireland which would be above water if it was depressed* 500 *feet, and to show the positions of the escars and gravel deposits with reference to the islands which would be formed. Signed* HENRY JAMES, Capt. Royal Engineers."

This map was placed beside a geological map of Ireland to show that elevations and depressions do not coincide with local geological disturbances, but with "surface denudations." The map, coloured black on a blue ground, shows two groups of more than 450 small islands. Their shape is irregular; but long narrow points trend south-westward; blunt ends are generally towards the north-east, and cliffs face the Atlantic and the north-west. Beside these maps were placed a travelling map, with notes of observations made in Ireland, and shaded Ordnance maps of Scotland, with thick ice, drawn to scale. Coast-lines of the supposed Irish archipelago correspond to many inland cliffs. "Drumlins," escars, osar, kames (Gaelic "ceum," a foot-path), and ridges of drift described by Messrs. Close & Kinahan, mentioned in this paper, shown on shaded Ordnance maps, and conspicuous in all glaciated countries known to me, are shown here to correspond in direction to the probable run of tides in sounds and wide passages less than 500 feet deep. These now are passes, hollows, lowlands, undulating plains of sands and gravel, bogs and large lakes, in Ireland; the islands now are isolated rocks with the shape of "Crag and tail," and

removed from hollows and from low grounds in Ireland is manifest. The excellent maps and sections of the Geological Survey, by showing what is left, prove that a great deal has been removed; but this can best be seen on the ground.

VI. *In Antrim* the hills left were shaped out of a late geological formation, which was spread over a wide area between Mull and Derry. At Red Bay, near Cushendal, in Antrim, at the sea-level, the rocks washed by the sea are coarse red-sandstone beds dipping about S.E. at a steep angle. I believe them to be New Red Sandstone. Their strike extends inland S.W. In that direction the broken edges of the beds of sandstone are covered unconformably by nearly horizontal sheets of igneous rock, upon which rest beds of chalk, which are covered by more sheets of igneous rock and ironstone. From marks which I found amongst these igneous rocks, it is certain that they were fluid and flowed as lava does, or the slag from a furnace. The basalts of the Causeway and elsewhere are columnar, like the rocks which flowed out of Snæfell, in Iceland *.

The chalk contains flints and fossils; and it certainly was deposited horizontally at the bottom of the sea, over a wide area. This whole threefold series still lies nearly flat, or slightly inclined, upon the sandstone edges which strike under the Antrim hills. This is an old surface of denudation buried under newer rocks.

The region has been faulted and has been undermined by waves, so that cliffs abound along the coasts; but it has also been ground and worn from above, so that iron ore and chalk crop out at points widely separated and at different levels. In crossing the Antrim hills, ironstone workings in the edges of flat beds appear on the turf of rounded slopes, on opposite sides of glens and hills and "cols."

They show that hollows have somehow been grooved out of flat beds of chalk and basalt, whose thickness can be measured along the escarpments next to the sea. From the hill-tops to the sandstones is somewhat less than 2000 feet; and that is a vertical measure of solid rock which has been taken away in shaping the Antrim glens and the Antrim hills, since the upper basalt was formed.

Westwards from the Antrim hills, on the other side of Lough Neagh, at about 40 miles from Red Bay, is a hog-backed ridge called Slieve Gallion (Mount Storm). The long axis of this ridge runs about north and south; it is about 1800 feet high, and it may be eight or nine miles long. It is the most conspicuous hill in the region. Up to 1200 feet the base of this hill is sprinkled or thickly covered with the drift, which also covers all these low grounds. Above the level of the drift it is easy to see that the bare body of Slieve Gallion is made of beds of hard stratified metamorphic rocks, dipping about northwards at a steep angle, and striking westwards through the ridge. At the northern end, capping this

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groups of hills scored horizontally by ice. The problem is, whether the Irish hollows ever were filled with solid ice; if so, to what height the ice-level rose, and how far the ice-field extended during the last glacial period.

* Rubbings and specimens of igneous surfaces were shown in illustration.

hill, are the edges of beds of chalk covered by basalt, which correspond to beds at distant points which may be seen from the hill-top as in a geological model. The chalk formation here is thinner, and it dips northwards at a low angle. It crops out at the sea-coast, in Lough Foyle, northwards, in Belfast Lough, at Fairhead, and all round a great solitary dome-shaped mountain, Slieve Lude, which rises above Ballycastle. At Slieve Gallion these newer beds rest unconformably upon the edges of older beds, as they do forty miles away at Cushendal. There is nothing in the present surface-forms of these hills to indicate their structure. The chalk and basalts, and the older rocks upon whose edges they were poured out and deposited flat, have been worn away together over a large area in this region for a depth equal to the height of hills at opposite sides and ends of Lough Neagh. The "cap" on the top of Slieve Gallion is a remnant of a great sheet about forty miles square at least; and rock taken away from hollows since the basalt formed was about 2000 feet deep.

Near the southern end of Lough Neagh and near Dungannon and Cookstown, the rock-surface is laid bare in quarries. The edges of sandstone beds of the coal-formation are crushed and shattered. Fragments are close to the rock, up in the Boulder-clay, which caps the quarry, together with hard smooth grooved boulders of granite and metamorphic rocks. These last abound at Cookstown, between Slieve Gallion and Dungannon. On the slopes of Slieve Gallion they rise to a height of about 1200 feet. In the low country the drift is packed in long high ridges. Some of the stones came from a distance; for there is nothing like them in the coal-field.

Southwards, near Armagh, and on the shores of Carlingford Lough, I found scratched polished flints and angular flints, amongst débris of the coal-formation, and basalts, and far older rocks. According to other observers, quoted by Mr. Close, "Antrim Flints" are found in gravels about Bray, near Dublin, and even as far south as Waterford; Mr. Froude brought me flints from Bray. These flints travelled southwards, and did not go northwards. I could find no flints or chalk north of Donegal Bay and Lough Swilly. About 2000 feet of basalt and chalk, of coal-measures, and of older rocks, upon which they were deposited, certainly were crushed, and broken and ground off an area of more than forty miles square about Lough Neagh, between Lough Foyle and Belfast Lough, Slieve Gallion and Fairhead.

Along the sea-coast between Fairhead and Larne, the sea is grinding rocks at the sea-level so as to bring chalk and flints to one polished surface. At a higher level the sea has made a series of caves which can be seen from the road. The same engine has undermined promontories, so that masses have fallen leaving cliffs with talus heaps, and cliffs from which the talus has been removed. In these cliffs the same forms are repeated all the way from Larne to Lough Foyle. They may coincide with faults; but I could find no faults coinciding with the coast.

Within this area are the marks of two great "denuding engines."

On the surface are marks of glaciation, which wore the rock and shaped the surface, and carried the débris southwards to Waterford, along a wide hollow which goes from one end of Ireland to the other, along the courses of the Ban and the Waterford rivers.

At the edge of the country are marks of horizontal undermining at "the destructive plane of the sea."

The marks of rivers and weather are also plainly seen (but they are insignificant about Lough Neagh) in plains and highlands. The amount of weathering is measured on quartz-veins, which retain glacial marks and stand out a couple of inches at most from the weathered surfaces. Rivers work only in their narrow beds; and most of them still flow on drift in low grounds. Since ice vanished and the land rose, these last-named engines have done little work.

VII. *Limestone.*—I will take another case in which the main hollow trends N.W.

The Sligo hills to the south of Donegal Bay are steeply scarped plateaux with cliffs and talus. The outline is often like that of the Antrim coast; the plan is like that of the Antrim glens. The chief difference in the forms of these two sets of hills is in the greater steepness of harder slopes in Sligo. Ridges end in sharp peaks like needles off the Atlantic coasts.

The tops of these hills and their high plateaux are made of flat beds of blue Mountain-Limestone, resting conformably upon grits and sandstones.

Cliffs are fractures; and some of these may coincide with faults. If so, I could not find them.

These beds were deposited horizontally at the bottom of a sea, long before the Antrim chalk. Elsewhere they have been greatly disturbed and bent into basins, notably about Lough Neagh, in the coal-field near Dungannon. Their geology is studied because of the coals which accompany Mountain-Limestone in Ireland and elsewhere. But about Beinn Gulban, famous in Celtic tradition, the beds are flat or slightly inclined. Like Antrim chalk, their edges appear on the sides of hills, in deep glens, at points, in "cols," and in cliffs. It is manifest on the ground that these Sligo glens have been hollowed out of a raised plateau, and that more than 2000 feet of limestone and lower beds have been carried away from large areas in this region about Lough Erne and Donegal Bay. Not one sample of Mountain-Limestone could I find in drift about Dangloe and the northern end of Ireland; but the low lands of Central Ireland are thickly covered with limestone-gravels. At Galway are sections of Boulder-clay full of scratched polished fragments of limestone; and great blocks of it have been carried on to hills about Kenmare, in Kerry, in the south-west. Like the flints, the limestone-drift travelled southwards. Measuring from the limestone in Sligo to the plain, about 2000 feet of rocks have been removed. The fragments did not go far north; but a great stream of ice certainly travelled from Lough Erne north-westwards into Donegal Bay. The marks are well preserved at Bally-Shannon on sandstone.

The Irish coal-fields now are patches scattered about the country,

which appear as spots upon the Mountain-Limestone in geological maps.

After seeing the destruction worked upon Dungannon sandstones, and the denudation of regions about Lough Neagh and Lough Erne, it is also seen that engines able to do such work may have destroyed coal-formations over the whole area of "denuded" Mountain-Limestone in Ireland. But if they did, then the low grounds are chiefly hollows made by the same engines which destroyed the Antrim chalk and Sligo limestone. Weathering and rivers could not and did not do this work, which I attribute to ice and the sea.

VIII. *Valentia.*—At the other end of Ireland, at Valentia, near the telegraph station, is a bank of Boulder-clay scarped by the sea. Slate rocks have there been crushed, smashed, and ground to powder. Chips remain in the clay so arranged as to prove that the engine which here crushed the solid rock came from the mainland down certain deep glens, split on Valentia Island, and went seawards on both sides of the island.

An instantaneous photograph of withered leaves caught up and whirled along by a strong wind might give some notion of the arrangement of chips of slate in the clay at Valentia. But in the immediate neighbourhood are finely polished, hard, grooved slate rocks, which prove that a great stream of heavy ice passed into Dingle Bay, moving north-westward after it split on Valentia Island and crushed the softer slate. The other half of this stream went to sea westwards.

IX. *Ice and the Sea.*—At these three places, about Lough Neagh, Lough Erne, and Valentia, the destruction of rock is recorded, as the quarrying of slate is at Valentia and at Bangor, by remnants left standing in quarries. At these three places marks of glacial action upon a very large scale abound, and extend vertically from the highest tops to the sea-level. But these glacial marks upon the surface commonly end abruptly at the brink of tall cliffs, which the sea is undermining and has undermined.

Off the south-west coast, far out at sea, tall peaks and scarped rocky fragments, the same in all particulars as rocks in neighbouring points, stacks, rocks, and needles, out to the Skelligs 700 feet high, are monuments of havoc wrought by the sea, after the ice-engine had struck work. Upon these outliers all the power of waves and weather now spend their utmost force; and the effects are manifest in cliffs at all the exposed points in the south-west. It is easy to see that Irish rocks have been greatly worn from above, and that ice did a great deal of the grinding. It is plain that the sea now is destroying the land by undermining it. The shape of Irish lands and coasts I attribute chiefly to the working of these two engines, ice and the sea.

X. *Glaciation.*—Glacial marks can best be seen amongst bare rocky hills, where rock-surfaces are most exposed, and where the shape of glens and hills, which are grooves and ridges in the solid, can best be distinguished from piles of loose drift. The structure of hills can

be seen; but solid rocks and their surfaces are buried out of sight in low lands.

Accordingly the districts chiefly studied for glaciation were mountain-tracts.

1st. The coasts, loughs, and mountains about Dundalk, Newry, the Mourne Mountains, hills in Down, Antrim, and Londonderry, as far as Fairhead in the N.E.

2nd. The mountains and sea-loughs in Cork and Kerry in the S.W.

3rd. Donegal, Sligo, Mayo, and Connemara, in the north and west.

4th. The coast was seen from a yacht, and from a steamer which visited the Lights, from Valentia, by Cape Clear and Dublin, round to Malin Head and Instra Hull.

5th. Points were also looked at in central districts about Dublin, Kildare, and Galway, Armagh, Omagh, Dungannon, Enniskillen, &c.

6th. Railway-cuttings and roadsides were watched from trains and cars; and every likely spot that could be reached was examined for ice-marks everywhere.

Where ice hardly exists it is necessary to consider the ways of glaciers and icebergs, and their work of grinding rocks and carrying the débris. I have tried to apply knowledge gained in rambling about the world during many years to rocks in Ireland.

In studying Irish "tool-marks and chips" I tried to assign them to natural engines, like those which I have seen shaping the earth's surface in the Alps, in Scandinavia, in Iceland, and in America, afloat and ashore.

XI. *Slieve Liag.*—I have said above that I attribute most of the rock forms in Ireland to glacial and to marine action. In Donegal, to the north of the bay near Carrick, is a peninsula of high ground jutting out into the sea, and making the northern horn of the bay. The end of it is a high mountain called Slieve Liag (stone or pebble hill); it is nearly 2000 feet high. Seen from near Beinn Gulban in Sligo on the other side of the bay, or from the Carrick Hotel at the foot of the mountain, it looks like any other Irish mountain with steep undulating sides. On the north the hill-side is covered with drift. From the head of "Glen river" and from all the high grounds to the east, down all the hollows which now contain rivers, at some late time, a great sheet of glacier-ice slid and flowed towards this tall hill, which split the flood, turned it aside, and shunted part of it out to sea through Teelin Harbour, S.W.

There can be no question about this part of the record. Glacial striæ are plain and perfect in quarries and gravel-pits, on rocks of many kinds, on veins of glassy white quartz, on pudding-stone, which is like a rude pavement of rolled stones; on hill-tops and in river-bottoms. I have rubbings of them.

The sheet of ice certainly travelled some twelve or fourteen miles downhill, some 1500 feet; and then some of it was forced up a steep incline. At the preventive station at the mouth of Teelin Harbour it went over the hill some three or four hundred feet high

out to sea. The landward sides of these hills are all rounded, curved, glaciated rock-surfaces, weathered or well-preserved, on which are drift-ridges, sheets of drift, moraines in perfect preservation, and all other marks of glacial action.

The ice-engine has ceased to work; but the tool-marks and chips are there about Carrick.

The seaward sides of these hills are marks of the sea, which is still at work in full power.

The sea is undermining these hills: they have long been undermined by the sea; and one side of Slieve Liag has been removed.

The highest top is close to the verge of a broken escarpment nearly 2000 feet high, facing the Atlantic. To look up from a boat is to understand the working of the sea upon a coast. At several places at the base of cliffs are beautiful white beaches of hard rounded pebbles arranged in the usual sweeping curves. At high-water-mark these pebbles, driven by all the force of Atlantic waves, have hollowed a groove in hard white quartz rock, some four or five feet high, of varying depth, and parallel to the water-line. The rock-surface is smooth as polish can make it, as smooth as glaciated vein-quartz on the other side of the hill; but the form of this surface is quite different. It is not grooved and striated in parallel directions by stones and mud fast in ice, moving steadily down in one broad continuous sheet; these surfaces of marine denudation are dinted and pitted, like the rolled stones which rest upon them, with which the sea pelts the rock when a gale is on. I have taken rubbings from many surfaces of this kind, and they are alike everywhere. Close to the undermined rocks are rocks which have been undermined so as to break and fall; and their angular fragments are rolling in the waves, to be made into pebbles for doing more work of the same kind.

Near the place are caves, some hardly begun, others bored into the rock far beyond daylight, with waves at work in them. On the calmest days they make a wild hoarse rattle and murmur as they mine the rock with its own ruins. I could see no faults to account for these grooves, cliffs, and caves.

Here, then, are two different sets of tool-marks on opposite sides of a hill, both telling the same story of the destruction of rock to the depth of at least 2000 feet by ice and the sea.

But this sea-cliff is a geological section 2000 feet high, and several miles long, crossing the strike in a curved sweep. A glance at it after looking at the surface inland demonstrates, better than a volume could, that the structure of the rocks of which these mountains are made has little to do with shapes common in Irish and other hills. The vertical fracture breaks through the edges of contorted quartz beds, which are seen meandering and curving in great arches, folds, and bends, right up to the verge of the cliffs and the scarped hill-top. Not one of these well-marked curves corresponds in any degree to the edge of the upper surface. The plane floor cut horizontally by the edge of the sea below cuts shear through all curves

indifferently. The undulating surface above cuts through them irregularly. The original surface of these crumpled quartz-beds has been entirely destroyed by denudation. Slieve Liag, with its grand cliffs and caves on one side and its glacial striæ on the other, demonstrates that the shape of Ireland in this region is chiefly due to glacial and marine "denudation." But all other Irish cliffs and coast-sections, and all the cliffs I have ever seen, tell the same story.

I leave it to professed geologists to measure the quartz-beds which are marked Old Red Sandstone on the map, and to calculate how much has been destroyed above since hard horizontal beds were crushed laterally and folded together like potter's clay. Upon similar worn surfaces later geological formations are piled, so far as I know any thing about them. It is enough for my present purpose to show that the upper surface of Ireland is a worn surface, in which the hardest parts usually are the highest, and that other old surfaces of the same kind are under newer formations, as shown at Slieve Gallion and at Cushendal in Antrim.

XII. *Ice-marks.*—In order to read Ogham we must learn that alphabet. In order to read older Irish records inscribed upon rocks by ice, we must learn the meaning of these signs. Snow is water. A snowball is plastic water; for it can be squeezed into moulds or pushed through narrow tubes. Glaciers are but plastic water. Water flows downhill. If it meets an obstacle while flowing, it runs up hill over it, or splits and flows round it. If a stream is stopped, it gathers behind the dam till deep enough to flow over it. A deep stream, like an ebb-tide, flows over all obstacles beneath the surface; but currents beneath the surface rise and fall, or move sideways, following the shape of sunken rocks and stones and sandbanks.

Plastic water in large glaciers moves like fluid water, and for the same reasons, but more slowly. A sheet of ice split upon the upper end of a ridge joins at the lower end. Two glaciers unite at a fork, as rivers do. Ice which has tumbled over a rock, like water over a fall, "regelates." It is plastic and it welds; so it mends like a broken snowball, and flows on till it melts. A lump of putty gives a ready illustration of the movements of glacier-ice; for it is plastic and heavy, it moves slowly, tears and mends, and moulds itself upon the surface beneath it, as glaciers do. When heavy glaciers press upon or against rocks under them, strength must decide which is to yield. If a rock is crushed, fragments help to grind rocks too hard for crushing. If the ice yields, it leaves a track on the obstacle which turned it from its course. When a glacier melts so as to leave the bed of it for inspection, it drops the upper angular moraine upon beds of clay and stones which were under the glacier, and these upper and under beds of drift rest upon rocks which were crushed or ground by the ice and the stones. So long as these tracks endure, the last movements of the melted glacier are recorded by drift and by glaciated rocks.

Whatever theories may be formed as to glacial periods and the motion of glaciers, it is certain that *ice now moves slowly in di-*

rections in which water in equal volume would flow more swiftly. By this alphabet I will now try to spell out some of the ice-records on Irish rocks*.

1. *Small mountain-glaciers.*—In Norway, districts of varying area, from a patch as big as several Irish counties to a mere hill-top, still are covered by thick beds of snow and plastic glacier-ice. About Bergen long deep fjords a hundred miles long lead up to long deep glens, which are rock-grooves. These lead up to smaller branching glens of like pattern, of which some lead up to the ice-regions. The ice forms upon high plateaux. All these hollows are of one pattern. A section is like the letter **U**; they have steep rocky sides; and drift of sorts is packed in the grooves from the sea up to the ice. At the head of the Sogne Fjord in one of these long deep bare rocky grooves, about three miles from the sea and amongst cornfields, is a glacier called Supedledals Iis Brae. It is made of ice which falls from the ice-plateau down a steep rock-face. It falls in fragments, which "regelate" and form a pile which slides down into the glen, and shapes itself as any other plastic mass might do. It moves from the side of the **U** towards the centre; and it draws marks at right angles to the run of the main stream, and to the ebb and flow of the sea in the fjord. But the movement of this side glacier is parallel to that of small streams, which trickle down the side of the rock-groove and join the main river in the bottom.

In Donegal, between Gweebarra Bay and Lough Veagh, a deep groove crosses Ireland from N.E. to S.W., with a col 750 feet high joining hills which are about 2500 feet high. On the northern side of this straight bare N.E. groove is a mountain called Slieve Snaght (snow mountain). On the other side is a hill of about the same height. About Lough Barra, which is close to the watershed, the rocks on both sides and in the bottom of the groove are smoothed and ground; they are almost bare of vegetation: their structure can be seen as in a model; and they are glaciated. Opposite to a cliff at the base of Snow Mountain are fresh ice-grooves in a roadside gravel-pit. They come from the cliff and go towards the lake and the river. It is therefore clearly recorded that an Irish glacier, like the glacier in Bergen, once existed in this Donegal pass, which is a miniature copy of a Scandinavian rock-groove.

Glaciers of this kind may be seen in mountain-districts where glaciers have decreased in size. Tracks of glaciers of this class abound in Kerry, in Connemara, in the Mourne Mountains, and elsewhere in Ireland. They all came down steep inclines from high points near the grounds where snow first appears in autumn and lingers the longest in spring, as it does upon Slieve Snaght, in Donegal, which a native unused to Celtic called "Sniff Snaff."

2. *River-glaciers.*—In the Bergen district above mentioned some of the upper branches of the main glens lead directly up to the

* Dr. Tyndall's book on the 'Forms of Water' entirely confirms what is here said. His own experiments and those which he describes, new and old, prove that glaciers flow and weld when broken. A set of prints, photographs, and sketches were produced with rubbings, taken by the author during many years.

plateau upon which snow gathers. Down some of these mountain-glens flow glaciers from five to ten miles long. These flow down the hollows, and end in muddy rivers, which flow on in the hollows through drift till they get to the sea in the fjords. Marks made by these, and drift upon and under them, grooves upon rocks, lateral and median moraines, and banks of drift, boulder-clay, and sands and gravels, arranged by the river and by the ice down to the delta, are all ranged parallel to the sides of the rock-groove, to the ebb and flow of the tide, to the run of the main river, and to the motion of the glacier. Everywhere are marks to prove that the Norwegian glaciers are but remnants of glaciers, enormously greater, which have dwindled away.

In Gweebarra Pass I found marks near the sea parallel to the course of the river, which flows S.W. into a miniature fjord called Gweebarra Bay. Having seen Bergen glaciers and these two sets of marks, there is no difficulty about the meaning of this record. 1st. A glacier flowed S.W. seawards from the watershed down 750 feet some five or six miles to the fjord, and thence went off into the Atlantic. 2nd. Afterwards, when that glacier dwindled and shrank and melted, a smaller mountain-glacier still crossed the track of it, at right angles, from N.W. to S.E., descending from the top of Snow Mountain by a very steep incline, more than 2000 feet in a couple of miles or thereabouts. 3rd. That glacier dwindled and disappeared. But water melting from winter snows and rain-water follows both tracks. The glaciated rocks in Gweebarra Pass are wet by streams which run from the top of Snow Mountain down to the lake from N.W. to S.E., and then run from the lake S.W. along the main groove into the sea.

3. *Glacier-forks.*—In Norway, and in all countries where glaciers exist in any notable proportions, two commonly join and flow on together. At the point of junction they press alternately upon rocks, which they mark alternately, producing cross grooves upon a flat surface, or grooves in different directions on opposite sides of a rock between the streams. In front of Derreen House, at Killmakillogne Harbour, in the Kenmare river, in Kerry, at the junction of two deep glens, are marks of this kind of which I have copies. Cross striæ are common elsewhere; but here the cause is apparent.

4. *Local systems.*—In Iceland is a scarped hill called Erik's Jökull *. The sides are cliffs with talus heaps; the top is a dome of ice whose base is a plateau of horizontal beds of igneous rock. As the snow-dome rises, the weight spreads the plastic base. All round this local system are stones crushed off the broken edges of flat beds of igneous rock; and these are ranged in curved mounds and heaps about the base of the dome. These terminal moraines belong to the hill, and they were pushed outwards towards the circumference. They were formed *under the ice*; for nothing but the sky is above this local system. At one point this snow-dome has extended its base down a hollow, and there is a small river-glacier of the usual

* See 'Frost and Fire,' vol. i. p. 428.

form, which ends in a muddy stream like the rest of its class. This is a model local ice-system.

Ireland.—On the top of one of the Mourne Mountains are marks which I attribute to a small local system of this kind. The marks are fresh, and a small stream of water runs along the striæ downhill, towards a hollow above Ross Trevor and Carlingford Lough, in which are piles of drift arranged in the form of a terminal moraine.

Mookish, in the north-east corner of Ireland, is a tall scarped isolated hill of quartz, with a plateau on the top. The shape of the hill is very like that of Eriks Jökull, in Iceland.

On the sides of *Arrigle,* near Mookish, are cliffs with talus heaps; the top is a plateau a few yards square. When glaciers were in Gweebarra a dome of ice certainly stood upon Mookish; and probably the small remnant of a plateau on the top of Arrigle indicates similar work.

5. *Iceland.—Lang Jökull,* near Erik's Jökull, is a long hog-backed ridge about thirty miles long, and covered with a sheet of ice. On the western side I could see no bare rock. On the eastern side, riding by Sprænge Sander, I saw that ice moves from the ridge down towards the low lands as water flows down the roof of a house.

At one place a great rock stands out like a garret-window in a roof. The ice splits at the back, flows down the sides, and meets again below at the base of a cliff. The direction of movement can be seen at a glance. The riven ice looks as if a flood had suddenly frozen while rushing down the steep side of this long hog-backed ridge.

The sea-face of the *Mourne Mountains* seemed to indicate a similar movement at some places; but I was unable to find striated rocks there. *Dun na Cuaich,* at Inverary, and *Sul Bheinn,* in Sutherland, are like this "garret-window" in shape; and the movement may be seen behind any stone in a moving stream of water.

Donegal.—The general shape of the hill country about the north of Ireland is a series of irregular furrows and ridges which trend from N.E. to S.W. or thereby. The ridge, on which Snow Mountain is the highest point, is bounded on the S.E. by Gweebarra Pass, the deep groove which contains two fiords, several lakes, and two rivers which flow out at opposite ends on opposite sides of Ireland.

On the north-western side the ridge is bounded by a shorter furrow called Glen Veagh. North of that groove is a broken quartz range with a similar trend, which includes Arrigle and Mookish, standing apart. It may be said that granite disturbed the sandstone and altered it and shaped the country. But what shaped the granite?

The Snow-Mountain range, like Lang Jökull in Iceland, sent down a flood into Gweebarra Pass, as I have shown. It also sent off a broad flood northwards. From the base of Slieve Snaght water now flows out of a corrie through nearly a hundred lakes, over granite, about eight miles to Dungloe, where a small river enters the head of a short fjord. The whole country is sprinkled with angular blocks of granite, as big as hay-cocks, hay-ricks, and small houses.

Here and there ridges of Boulder-clay and other kinds of drift aim northwards; and all the loose stones in these hills of drift seemed to be granite of the country. At Dungloe is a considerable ridge of granitic boulder-clay, parallel to the course of the river and to the fjord. Where the sea has newly washed this clay from the rock, glacial surfaces are perfect*.

The marks aim from the foot of Slieve Snaght, at the north end of Arran Island. Followed in that direction the marks still aim out to sea northwards and to the west of north. From rising grounds near the sea, Arrigle and Mookish are seen above the granite lowlands. At the base of the high cone of Arrigle are great blocks of grey granite resting upon the quartz; and all along the sky-line seen from Glen Veagh and from the Gweebarra Pass great stones are perched.

The solid granite is in the S.E. ridge of Glen Veagh, quartz is on the N.W. side of that furrow; and the granite boulders seem to have crossed from the Slieve Snaght ridge towards the N.W.

All recent glacial marks that I could find in this region indicate a local system of Donegal glaciers which moved as ice now moves about Bergen and in Iceland. In particular the ridge which divides Glen Veagh from Gweebarra Pass was covered by a sheet of ice like Lang Jökull in Iceland, which flowed off it as water flows off the roof of a house into gutters. The ice, according to its marks, once was about 2000 feet thick, and went out to sea; but it dwindled and shrank till nothing remained but river-glaciers, and then mouutain-glaciers of the smallest size, with one of which I began. (XII. 1.)

6. *Irish local systems.*—That which is true of Donegal is true of all the groups of mountains which I have visited in Ireland.

A smaller local system left conspicuous marks on the peninsula which ends in Slieve Liag, which I have already mentioned (XI.). Another was in the Antrim mountains. There moraines are entirely made of fragments of rocks of Antrim. Whole walls are built of boulders of basalt; and the Boulder-clay is brown. Glacial marks upon the rocks follow the run of water, beside rivers, from the snow-shed downwards. From Larne to Ballycastle the Antrim glens were filled with glaciers like those of Donegal, which were like those of Iceland. Another large local system was in the Mourne Mountains. Another had the Twelve Pins and other hills of Connemara for gathering-ground and starting-point.

Another was in the group of hills on the west side of Lough Neagh; another was in the Sligo hills; another was out near Achill Head.

A very large system was in the south-western corner of Ireland, with the high grounds about Killarney for gathering-ground and the sea for receptacle. This last has been described by Mr. Close, and by other writers.

Knowing something of all these systems, and of others of less size, it is proved, by marks about which there can be no doubt, that Irish glaciers, down to latitude 51°, were equal in area and dimensions to the largest local ice-systems in Iceland, which touches the Arctic circle. But the Irish ice-system was still larger at an earlier time.

* Specimens of glaciated granite were shown.

7. *The Northern Irish Ice-system.*—The most conspicuous moraine that I have seen in the British Isles is at a point at the northern horn of Donegal Bay, at a place called Clogher. It is marked by dots upon the inch-scale Ordnance Map. It is there nearly three inches long, and it consists of at least six parallel ridges of angular stones. The largest of these are as big as small houses; and they rest where they were tilted off the ice, like stones shot from the end of breakwaters at Plymouth and Holyhead. Above this conspicuous moraine is "Cruach Beg," a hill of puddingstone (? pebble-beds of the Old Red) which is glaciated up to the top, 860 feet. The marks run along the top and side of the ridge horizontally, parallel to the moraine, aiming over the sea at the low country about Lough Conn, and at the head of Clew Bay, beyond that low gap. Here is one side of the bed of a glacier as deep as the hill is high; but the other side was over in Sligo, beyond Donegal Bay*.

Following Donegal Bay round the coast, and looking to striated rocks, ridges of drift, and all other marks known to me, it seemed clear that the whole area of the bay, and all the lowlands about it, from Barnes Gap and the hills about it round by Lough-Erne side and Ballyshannon, past Sligo to Loch Conn, were covered by a sheet of ice which bore heavily upon a hill-top 860 feet high, at Clogher, near the end of Donegal.

But the low lands about Lough Conn are glaciated as Sweden is; and great stones, like those which are *in situ* about Clogher and Slieve Liag, are scattered about the low lands at which striæ point from "Cruach Beg" and Teelin Harbour.

Clew Bay is like Donegal Bay. The low grounds are all made of long ridges and furrows of drift which point westward, as do glacial striæ and other marks down to Achill Head, along the northern coast of the bay. From Barnes Gap, east of Donegal Bay, to the northern horn of Clew Bay, there was continuous ice moving seawards, as it appears to me. But that was not the limit of the Irish ice according to its marks.

Depth.—Vast time has elapsed since the local systems were united. The weather has worn out many tracks, and chiefly those which were highest and oldest. The ice was more than 2000 feet deep at many places; but it must have been far deeper. In Connemara is Shan Folagh, a ridge of hard quartz standing apart from the rest of the group of mountains, and about 2000 feet high. On this isolated top the rock is well glaciated, chiefly from the north-east.

The Atlantic is on one side; and the nearest block of ground of equal height in the other direction is in Antrim or in Scotland. Ice must have gone over this hill. I once thought it was drift-ice afloat; I now think it was part of the ice which covered Ireland from Donegal to Galway.

High marks.—Beginning with the smallest class of mountain-glaciers, Irish marks have led back to large river-glaciers, to small and large local systems, to a combination of several local systems in an estuary of glaciers in Donegal Bay, to the union of two estuaries in

* Rubbings were shown.

Clew Bay, to glaciation at 2000 feet upon a hill-top near Galway Bay. But this quartz hill stands there like the stone pillar at Penryn, to mark, 1st, the depth of the ice, and, 2nd, the depth of the rock which has been removed from that region. On lower hills are marks of local Connemara glaciation; but at the head of Galway Bay is a bed of Boulder-clay full of limestone from the central regions, resting upon rocks striated in the direction of the sea. A great body of ice at some time or other passed off Ireland from the N.E. to S.W. by way of Galway, according to the high and low marks which I more fully described in 'Frost and Fire,' and which are now mapped by the Geological Survey *.

The high marks upon Shan Folagh pointed the way to seek for more knowledge nine years ago. The lines ruled upon the hill-top were produced upon a map, and touched Cushendal, in Antrim. In 1872, after nine years, I went there to see what I could find. I found first unmistakable marks of a local Antrim system proportionate to the size of the hills.

Next I found out a tall trap-hill called Slieve Mish, and went to the top of it. I found it a great glaciated "Tor," beside a rock-groove which crosses the range. In the groove, at about 500 feet above the sea-level, I found and copied striæ pointing N.E. and S.W.; therefore this groove was filled with ice of some kind. The long axis of the hill is nearly north and south; the rock is weathered; but at the northern end it is deeply grooved. If these are old weathered ice-marks, as I believe them to be, then all the marks aim right over Ireland at the Twelve Pins of Connemara, and over the sea at the Firth of Clyde. In mapping the glaciation of Ireland a line may fairly be drawn from Shan Folagh to Slieve Mish, and the ancient ice may be reckoned to have been more than 2000 feet deep from one side of Ireland to the other, within the bounds of Ulster and Connaught. That makes the northern ice-system in Ireland.

Theoretical General Glaciation.

Of late years a school of geologists have taken up a glacial theory which their adversaries condemn. The advanced glacial theory, so far as I understand it, is that during a late geological period the whole of the Northern Hemisphere, from the Pole down to regions near the Equator, was covered by a continuous thick crust of ice. It grew then, as ice grows now, by evaporation about equatorial regions and by condensation about the Poles and about high grounds. From the Polar regions, where the ice was many thousands of feet deep, as from the chief condensing-point and gathering-ground, this general ice-system spread southwards, because any pile of plastic materials so spreads. No one imagines that all the water evaporated condensed at any one spot, at the Pole or elsewhere; but the greatest condensation was about the coldest region near the Pole.

Accordingly the ice moved thence with a general southerly movement, along meridians, during the greatest development of the last

* A specimen from the hill-top was shown.

glacial period. But if one half of the world was so covered, the other half cannot have escaped. The change in climate which produced this period of intense cold is theoretically accounted for by astronomical facts.

The whole theory was based upon many sets of observed facts which combine severally and in groups, and lead gradually from smaller to greater conclusions as the number of facts observed grows.

My observations made this year in Ireland, combined with the rest of my facts, have led me from small mountain-glaciers to a sheet more than 2000 feet thick, covering the northern half of Ireland. I have got a long way towards the most advanced glacial theory since I printed 'Frost and Fire,' in 1865; but I cannot yet see my way to a universal ice-crust. What would become of vegetation and animal life if the uppermost geological formation were everywhere frozen water? That being the advanced theory, and one difficulty, let me add more facts to my budget, and look at the other half of Ireland, with the most advanced glacial theory borne in mind.

8. *S. W. Ireland.*—Any map of Ireland shows the general shape of the south-western end of the island. The coast-line is that of a series of long sea-loughs. The country is a series of long ridges of high land, with deep grooves between, which trend generally south-westward on the strike. It will be argued that the strike accounts for the shape of the land. I do not think that it does.

The sea ebbs and flows in these grooves, and rivers come down through drift at the ends of the sea-loughs. Knowing something of Irish glaciation, one of these long ridges explains the rest.

The first place examined in 1872 was Bere Haven. There glacial action is conspicuous. Rocks at the sea-level are polished and striated, and Boulder-clay with scratched stones in it rests upon grooved rock in Bere Island. A hot day's walk there showed that ice which did this work came off the ridge from the flanks of the highest hill in sight, "Hungry Hill." It crossed Bere Haven, and went over Bere Island at a height of about 800 feet. It was very heavy ice according to the record. If the ice was at least a thousand feet thick, and moved down from the ridge on one side, as in case 5, it must have done the same on the other. In fact on the other side at Killmakillogue Harbour, and at Derreen House, two large local glaciers met and left their story inscribed in plain lines upon the rock. In the middle of this harbour is "Spanish Island." It is a pile of large glaciated rolled stones arranged in a crescent-form, with a small patch of scarped Boulder-clay ten feet high and a few yards wide left standing by the sea.

On this patch grass grows; and all the stones in the clay are finely glaciated. The north-eastern horn of this harbour is the scarped end of a long hill of Boulder-clay of the same kind, on which is a good farm, running parallel to the long arm of the sea which is called Kenmare river; and ridges like it are features in the landscape on both sides of the lough for many miles. To an eye used to look for

ice-marks, all the rocky hills are glaciated from top to bottom. From the fork at Derreen House striæ can be followed along the shore to the mouth of Killmakillogue harbour, where they bend south-westwards, and run parallel to the ridges of Boulder-clay. Up to the top of Knock-a-tigh, 1100 feet, striæ were copied off the rocks by rubbings. Near the top is a large perched block. At the base long deep grooves run under the long ridge of Boulder-clay. As I read this record, it means that ice flowed off this long ridge, as water flows off a roof, till it got into Kenmare river and the other gutter, Bantry Bay; then it flowed seawards S.W. 2nd. Small local glaciers afterwards cut through the ridges of Boulder-clay which were left by the large Kenmare-river glacier, and so opened the harbours of Killmakillogue and Scriob. The ice was more than 1100 feet thick in Kenmare river, and it probably was a great deal thicker; for the whole ridge is glaciated. Crossing the corresponding gutter to the opposite side of Kenmare river, all these marks are repeated at the corresponding harbour, and they recur down to Dursey Island; there the sea is breaking cliffs out of the hills. At Bally-na-Skelligs Bay all known glacial marks occur, as they do at Valentia. Three great sea-loughs at least, Bantry Bay, Kenmare river, and Dingle Bay, were the beds of enormous glaciers, which came from hills about Killarney as rivers do now. There can be no question as to the former existence of a great local ice-system in the south-west corner of Ireland. But when the northern half of Ireland was covered with ice, the Kerry system must have been joined to the system which flowed seawards at Galway and at Carlingford Lough. All these sets of facts combined prove that all the local systems in Ireland were united before they broke up into separate local systems. Join high glaciated points, change lines into planes, and the whole area of Ireland is beneath the level of ice which ground heavily on hill-tops more than 2000 feet higher than the plain.

9. *United Irish System.*—Since I first observed high ice-marks in 1863, many Irish observers have tested my facts published in 1865. In an able paper upon the glaciation of Ireland, published in the first volume of the 'Transactions of the Irish Geological Society,' the Rev. Mr. Close says that he found that which I had found upon the top of Shan Folagh.

Mr. Kinahan, the local geological surveyor in the district, sought for like marks on neighbouring hill-tops, and found them. His work, begun about 1865, was published in 1872. Messrs. Close and Kinahan have now published a pamphlet with a map of glacial marks about the heads of Clew Bay and Galway Bay, Lough Mask and Connemara. This map of the able and patient work of seven years confirms my own rapid observations. There was a very large local glacier-system in Western Connaught, which radiated seaward, and which joined other systems on the landward side, till it dwindled away there as elsewhere. It left an exceedingly complicated record in the low grounds, where systems met as glaciers did at Dorreen in Kerry, or where systems split behind hills. Taking the whole

map, the lower marks trend S.W., and avoid the mountains where they are not the marks of local glaciers born amongst the high glens, and high hills.

XIII. *The United Systems of Great Britain and Ireland.*—I now believe that Ireland was, like Greenland, entirely covered, that it became, like Iceland, partially uncovered, and then, like Scandinavia, nearly bare. But I cannot believe that Ireland ever was a patch of land covered by an equal area of thick ice bounded by the sea. During its Greenland period the Irish system must have been united to Scotland. Having got to Red Bay in Antrim I took a cast northwards by Fairhead to see what I could find there. As I have said, the Antrim hills are made of basalt and trap and chalk; and Antrim drift generally is made of Antrim rocks. At Cushendal are many great blocks of grey mica-schist; and these are strewn over the northern end of the Antrim hills, together with other stones which commonly occur in "Northern Drift." Along the sea-coast are steep grounds along which the road runs uphill and down. Some of the rocks hereabouts are metamorphic, with veins and dykes of granite in them; but I could find nothing *in situ* like the large grey erratics. Along this coast striæ run horizontally, and point at the sea-horizon north of the Mull of Ceantire, and towards the glen at the foot of Slieve Mish, which leads S.W. towards Galway Bay. Near the Preventive Station the hill-tops are white chalk, bare, or barely covered by fine green turf. There, and at Fairhead, up to heights of 850 and 1100 feet above the sea, numerous large erratics of the same heavy hard grey mica-schist rest conspicuous upon the hill-tops. At some places the builders of stone circles have gathered the largest blocks to crown the highest top, while smaller blocks are scattered where they fell. Along this ridge to the cliff at Fairhead these great erratics are strewn over the chalk. Produce lines ruled upon the hill-sides about Fairhead, upon a map, and they pass near Loch Killesport in Argyllshire. There, near Ormsary, is the largest erratic which I have seen in the British Isles. Thence glacial striæ cross the water-shed into Loch Fyne, and run up Loch-Fyne side, past Inveraray, where all the hills are glaciated till they lead up to hills near Tigh an Dromma, about Loch Awe, Loch Lomond, Glenfalloch, Glen Dochart, &c. in the Perthshire highlands. But rocks and erratics in Ceantire, in Cowal, and about the central highlands of Scotland, cannot be distinguished from the erratics upon the chalk hills at Fairhead in Antrim.

XIV. *Maps.*—If a man could grow on the scale of a mile to the inch, he could see all Scotland at a glance. The ordnance survey of Scotland, drawn on the scale of an inch to a mile, has now advanced so far that four sheets joined give common men a giant's view of the low country between the Forth and Clyde, with parts of the highlands to the north and south.

Looking down upon this miniature country as a giant seventy miles high might look upon Scotland, we can see that it is crossed diagonally by a big groove with a broken ridge in the middle of it. After sun-down on a fine clear cold evening, November 13, 1872, I

saw through the northern part of this groove from Callander, and saw from under a roof of gray clouds the ends of distant ridges like blue pyramids against a hard yellow sky. I went down the side of the groove to Stirling, and along it to Edinburgh. There I took rubbings off rocks. I saw that which is better shown upon the inch scale. The large rock-groove is fluted by smaller ridges and furrows. When these are examined on the ground, small ice-marks are found wherever they have not been destroyed. Ridges of gravel and of Boulder-clay, whose longest axes correspond to rocky hills of like shape, abound from Strathmore to the Clyde, from the "east neuk" of Fife to the west end of Bute. The Bass, North Berwick Law, Edinburgh, Stirling, Dechmont, Dumbarton, Ailsa, and hills which rise through water and drift all the way to the west of Ireland, are alike in form when they are mapped or seen. Any one can see on this map that which I have seen in travelling about for many years. This big Scotch groove is dug out of a great many kinds of rock, as I believe. The softest are in the deepest hollows, and the hardest are generally highest. Some broad engine has certainly passed over these low lands. The sea has been there; for shells are in drift. Ice was there; for Boulder-clay rests upon glaciated rock.

Problems unsolved are, the kind of ice and the extreme size of it, the power which was set to move it, the work which it did, and where and how the work was affected by the material upon which the engine was set to work.

XV. *As to the material.*—A series of straight parallel ridges are drawn between Callander and Dumbarton, and contrast somewhat with the rest of these forms. At Callander, at Dumbarton, in Arran, in Antrim, and in Donegal are edges of beds of Old Red Sandstone. The ridges drawn on the Scotch map are as the grain in carved wood*. At Slieve Liag is a cross section which shows that these beds have been kneaded and crumpled up edgeways like dough. But the forms shown on the map do but record the relative hardness of denuded beds. In the higher country are a different set of forms. Glen Falloch and Loch Lomond are at right angles to the large groove, and cross the strike of the Old Red Sandstone, and of the older rocks of the central highlands, of Argyll and Perth. The spurs of Beinn Lomond, parallel to the Loch, are long ridges and furrows which cross the strike and the edges of the Old Red Sandstone. Faults, and cracks, and breaks abound in the district; but the Ordnance Map and the country itself do not show them. The Geological Maps do; but the shapes of Scotland and Ireland do not accord with their numerous faults.

About the head of Glenfalloch, from all the glens and corries about Tigh an Dromma (Ridge House) flow rivulets which go north, south, east, and west through deep glens; they grow to be rivers, and join the Forth and Clyde, the Tay and the Awe. In each glen is a flat of water-drift fringed on both sides by rows of hillocks of older glacial drift, containing large smoothed stones of many kinds. At the end of each glen are piles of glacial drift in the form of

* A carved model of the hills about Inveraray was shown.

moraines; and marks of glacial action are everywhere. Looking up from these deep glens at the hills in fine frosty sunny winter weather, after the first November snow in 1872, I saw the edges of beds of rock near the highest tops in every direction.

They dip at various angles, and in various directions; they slope down one side of a glen, cross it and rise up the opposite hill-side. I could see no faults to account for the shape of the country. I saw beds on the east side of Glenfalloch, in the face of A Bheinn Mhòr (the big hill), passing along jagged peaks on the ridge, and along the hill-face for many miles, like the grain of wood in a carving.

They proved, by simple inspection, that these peaks were made as the teeth of a saw are, by working out part of the solid.

It seemed manifest that all these radiating Scotch glens were carved out of the long folds which extend longitudinally from N.E. to S.W. according to the Geological Maps. Looking north, south, east, or west, the hills and dales in this region appeared to me as they appeared to Sir Roderick Murchison and Professor Geikie, "monuments of enormous denudation." But the débris next the rock is everywhere glacial, and the work of running water is everywhere insignificant when compared with the glacial work which water is destroying.

I could find no record of the presence of the sea about the watershed, which is nearly a thousand feet above the sea-level. All the marks tell of the action of enormous local glaciers, which radiated from this tract.

From this watershed of Scotland, down by Glenurchy, and Loch Awe, and Loch Fyne, and Loch Lomond, and Loch Long, swept great masses of ice which ground the whole of the mountain-ridges between these grooves. It ground the whole ridge of Ceantire. From Glenfalloch to Dumbarton down the Clyde, over Bute and past Arran, ice more than 1400 feet thick went horizontally towards Belfast Lough.

The Ordnance Survey have furnished a map of Arran which is as good as a model. You take the giant's view of it, and see the shape of the local ice-systems plainly recorded. On the ground all known marks prove that all these glens contained glaciers.

But all round the western coast are marks upon rocky points, which prove the passage of ice horizontally between Arran and Ceantire at more than a thousand feet above the present sea.

In the Isle of Man the hills are scored horizontally, and scratched stones and blocks of quartz are near the highest top.

As I now read my record the ice was continuous between Scotland and Ireland.

XVI. But on the top of Scotland near Dalwhinny, and near the top of Beinn Wyvis near Dingwall, I have seen great blocks of the same stone which I found upon chalk hills at Fairhead in Antrim. I have followed ice-grooves and erratics over Scotland and over the backbone of Norway. I left the tracks only at the edge of the Polar basin. They seemed to cross hills into Finland and Russia.

Coming south from these high latitudes, I left blocks of Finnish granite in plains near Berlin. In my view Irish glaciation is but a small part of something far greater, which acted continuously from the White Sea down to the Kerry sea-loughs; and the question now is, what was the nature of the engine that did all this vast glacial work?

XVII. *Land-ice or sea-ice.*—Nine years ago my smaller collection of facts led me to account for all glaciation by causes upon the extreme scale of the existing arctic current and Greenland ice, which I travelled to look at afloat off Labrador and Newfoundland. As my collection of facts grows, I am led towards something still larger. Even an extension of the climate of Greenland to Ireland, and the shifting of the arctic current to the Baltic, would hardly account for marks which I have seen and which I have tried to describe here and elsewhere. When I review all that I have seen in Finland and Scandinavia, in Iceland and Labrador, in Greece, in the Alps, in Spain, and in America west to the Mississippi, and try to combine what I have seen with all that I have learned from writings, maps, and pictures, the whole of my knowledge of facts leads me to a very great extension of all glacial systems, and to a union of many to form one great Polar system, which moved southwards, and reached far beyond the latitudes of New York and Rome. Near New York, for example, the ice came from Canada, and it was over 2000 feet thick when it passed along the scarped face of the Catskills in the direction of the flow of the Hudson river.

I thought that icebergs floating in an arctic current would account for horizontal grooves, which I copied by rubbings all the way up the face of the mountain. The uncertainty of the marks upon the top, where water would flow into the next valley, confirmed that opinion. I now begin to think that the ice which passed over the site of New York seawards in the latitude of Madrid may have been part of a crust which spread from the Pole down to that latitude at least, and there was over 2000 feet thick. My theory has grown with my knowledge of facts. My separate icebergs have joined together. To all that I have said in 'Frost and Fire' I have added more solid ice, and, as I believe, on solid grounds.

XVIII. *Theory.*—This is the purport of the story which I have deciphered from glacial rock-inscriptions in Ireland and elsewhere:—During a late geological period, land in the northern hemisphere was covered by thick crusts of ice, like ice in the southern hemisphere. The crust was continuous then down to low latitudes, as it is now in high southern latitudes. Where it ceased to be continuous, mountains supported large and small local systems, as mountains now do. But the separate systems approached and may have reached to the equator, as said by Agassiz. There was then, as there is now, a general movement from north to south in high latitudes. Where the water was shallow, glacier-ice grounded; where it was deep it floated; and the depths at which ice grounded were proportionate to the depth of the ice. At 2000 feet berg-ice, which

was glacier-ice at first, grounded in 1800 feet of salt water; at 3000 feet, in 2700 feet or 450 fathoms, according to measurements which I made off Labrador on ice from a stranded berg. The general southerly movement was turned aside locally. At some time there was movement in a south-westerly direction from the Baltic by way of Götheborg and across Scotland by way of the Forth and Clyde, and apparently across Ireland also. There was a wide and extensive movement south-eastwards from the east of Scandinavia down by the course of all the Swedish rivers, and over Finland past St. Petersburg. On the northern shore of the gulf of Finland marks upon granite indicate very thick ice moving over a wide area. There have been a succession of movements. When each glacial period was at the greatest, and climate began to warm up, each great mountain system in a low latitude separated from the crust and became a separate centre of movement. The general system has now shrunk far within the arctic circle; but Spitzbergen, Iceland, Greenland, patches in Scandinavia, and in the Alps, still are gathering-grounds for snow and bases for local systems of glacial action. All these were larger by far. That at least is certain. There can be no question about the enormous extension of the alpine ice-system, and of the transport of stones by ice from the Alps far northwards into the plains of Germany, and far southwards into the plains of Lombardy.

To see Norway and Sweden is to understand that the whole area was one great sheet of glacier-ice moving far out to sea on the N.W., and far out into the low grounds of Europe on the S.E. A former great extension of glacier-ice from existing centres is proved.

The next problem is to make out whether the Scandinavian and Alpine systems met in the low grounds of Europe, and there joined the general Polar system; and if so, how far and to what latitudes this general compound system of glacial movement extended, how it moved, and what work it did. I believe that the general movement and the united crust of ice once reached as far as Washington in America, and as far south as Greece on this side of the Atlantic, and probably united east and west round the world. The leaders of the vanguard teach, as I understand them, that the crust reached nearly to the equator.

XIX. *Ireland.*—The later record in Ireland now seems to read thus. From Kerry to the White Sea there was a continuous ice-system of vast mechanical power, which has gradually retired northwards. As it retired it broke up into separate local systems; as the main system retired northwards from them, the local systems retired from the sea and from the plains up the hills. As the plane of perpetual snow rose from the plane of the sea above the highest hills in Ireland, the Irish local ice-systems also rose till there was no base left for snow to rest on. That which I have seen of late is the record upon the surface of Ireland, the shape of which I attribute chiefly to glacial action, as I have said.

XX. *Under water.*—As I now read marks in Kerry and on the Scotch and Norwegian coasts, ice during the last glacial period

was more than 2000 feet thick when it went to sea. Ice of that thickness would slide along the sea-bottom till it reached water 1800 feet deep (300 fathoms). Between Ceantire and Fairhead the deepest sounding given is 456 feet; between Islay and Instrahull the deepest is only 312 feet. The limit of 600 feet (100 fathoms) passes far outside the British isles. The limit of 1800 feet is out about Rockall. According to charts, the bottom is chiefly made of sand and shells and mud, the light "drift" which tides pack in harbours. But the lead finds rocky hills and deep hollows under water, and trawlers have fished up great boulders south of Plymouth.

Late changes in the level of sea and land are proved by raised sea-margins, by sea-shells far inland, and by submerged peat in the south of Ireland and off Wales. But if the sea were 1200 feet deeper than it is, glacier ice 2000 feet thick might still slide along the sea-bottom from Scandinavia to Kerry.

XXI. Landscapes of the glacial period, which I now picture to myself still, are but magnified images of real landscapes. In Greenland and in Spitzbergen, and notably in south-polar regions, very thick broad sheets of ice slide off land into the sea. These crusts do not end suddenly at the water-level; they break or they slide along the bottom like rafts on slips till they get out of their depth. The ice-rafts meet and join like glaciers on shore in shallow straits about Greenland. Such rafts enlarged would unite if they met in mid ocean. It is well known that glaciers on shore are forced over hills by sufficient pressure from higher hills or from higher snow-heaps. The same glacier partially floated by water can be driven over sunken hills by less force.

Terrestrial and amphibious glaciers are ice, and have greater mobility for weight decreased by partial flotation. Awash in moving water and aground, a glacier pushed seaward is easier to move and is moved by more forces. Ice that slides off Greenland south-eastwards and north-westwards is turned south-westwards by the Arctic current. It would be affected by that current if it were aground all the way to Iceland and Labrador. Were the Arctic current transferred to the Baltic, and Scandinavian ice enlarged till the whole of that sea was one wet glacier, the laws which govern the circulation of ocean-currents would not be repealed. If the local systems of Greenland, Iceland, and Scandinavia were united in the Atlantic and aground in its shallows, water left fluid in deeps and further south would still move in obedience to existing laws, and would still move ice adrift or awash in it, however large and deep the ice might be. Glaciers did move through hollows which are lake-beds now. I suppose that a far larger glacier than any now extant moved along the beds of shallow seas. In striving to picture the glacial period I invent nothing; but I strive to shake off ideas of size. The whole world is a very little thing to the solar system; but so far as we know, the same mechanical laws govern the movements of the whole machine and all its parts. The authors of the 'Reign of Law' and of the 'Theory of Lakes' will agree with this.

XXII. *Ice-marks.*—If I reduce a country on the scale of a mile

to an inch, I reduce glens 12 miles long to the size of glacial striæ a foot long, and they are alike in shape. If, on the other hand, I begin with hair-lines engraved by ice with fine sand upon glassy quartz, and magnify them with a microscope, they take the proportions of larger striæ upon the same stone. I can get to grooves like Gweebarra and Kenmare river by easy steps along Irish rocks. But hair-lines, Irish glens, and Norwegian fjords are all grooves of one pattern, though engraved upon different scales. If ice made one set of grooves, bigger ice might make the biggest. A finished ordnance-map and a rubbing taken off a glaciated rock show that glens and striæ are very like when the large scale is reduced from a mile to an inch. A very little chipping and shaping would convert a few square yards of glaciated Irish rock into a tolerable model of the island of which it is part. I have not grown to be 70 miles high; but, in growing to be 50 years old, I have seen as much of the world as if I had looked down upon it, and I remember, on the reduced scale, as if I looked upon a model. Looking thus back upon all the countries which I have seen, the hills and dales appear to record that the very same ice-engines which are shaping the earth's crust in high latitudes and in high lands, also shaped the surface of the British isles when those engines were larger, longer, broader, deeper, and heavier.

XXIII. *Sea-marks.*—Having seen and copied sea-marks at many places, I see that shelves and floors carved all round Ireland by the sea will unite in time. Unless Ireland is raised, it will be polished off the face of the earth by waves. But the new surface will only be like older buried surfaces, and like the surface of Bute or Anglesea, or any other low country, which is like a geological map without mountain-shading.

Looking at the work done by the sea round the Irish coast, and at ice-work and drift and sedimentary rocks, no measure for "Denudation" is left, except the full sum of sedimentary rocks from Irish mud to Laurentian gneiss and the granite, which was sedimentary before it was last fused.

Wide hollows and narrow grooves were dug out of the solid in Ireland since the formation of Antrim Chalk and Basalt. Most of that work still bears the marks of ice. Enough of glacial débris is strewn over the low lands to fill up many of the grooves in the hills; and these records are carved upon Irish hills in plain lines, which a child may soon learn to read.

XXIV. *Conclusion.*—Denudation is part of geology. Ireland has been largely denuded. Glacial and marine action are the most powerful known to me. Glaciers and the sea shaped Ireland, as I believe. Rivers and weathering have done little to obliterate the tool-marks of ice and the sea, since the end of the last of a series of glacial periods *.

* April 3, 1873. It has been pointed out to me, that as early as 1840–42, P. Merian, of Basle, showed that ice-fractures are completely closed. The first maker of a snowball proved the "regelation" of ice-crystals under pressure; and the fact is now generally understood.

Discussion.

Prof. Ramsay agreed in the main with the views of the author, and with the opinion of Agassiz as to the great extension of cold at a certain period both in the northern and southern hemispheres, though he could not carry the theory quite so far as to leave merely a narrow equatorial belt unaffected by ice. He had, however, never seen any mountain-region in the northern hemisphere on which there were no traces of glacial action. As to Ireland, he knew of no portion of its surface which had not been glaciated, and the great striations actually extended, as they do in Scotland, right over the watersheds, and were evidently unconnected with any merely local features. At the same time, even where the general current of the upper portion of the ice was constant, yet there might have been and probably were, undercurrents, the course of which was determined by the form of the country traversed by the ice. He was not certain that the present features, resulting from denudation, were rightly attributed to glacial agency alone, as other causes appear to have been at work. He instanced cases of enormous denudation at early geological periods which it was difficult to trace to any glacial action. He thought that during the Glacial period the main features of the country were to a great extent modified by the great ice-sheet which capped it, without its having had so extensive an effect as that sometimes attributed to it. Still sufficient changes had been made on the surface to cause the rivers which were resuscitated after the close of the Glacial period to take new courses. The existence of old river-valleys, partially obliterated by glacial débris, proved to his mind that hills and valleys, and a diversified surface, existed previously to the Glacial period to almost as marked an extent as they do at the present day.

Sir Henry James observed that, having at one time been in charge of the Geological Survey of Ireland, he could indorse the views of the author as to the glaciation of that country, though he agreed with Prof. Ramsay as to the probability of valleys in Ireland and in Scotland having existed before the Glacial period and guided the flow of the ice. These no doubt were intimately connected with the varying hardness of the rocks.

Mr. T. M'K. Hughes remarked that there was no necessity for a polar ice-cap from any secularly recurring cold—seeing that the difference of temperature, known as a matter of observation to be due to geographical causes, was so very much greater than any variation of temperature which had been shown to be possible owing to astronomical combinations, that the astronomical causes might be neglected. He showed that the glaciation which was relied on as a proof of the passage of large masses of ice from the north, did not appear to come from the north pole, but from local centres, such as Scandinavia, Scotland, and the mountains of Wales and the N.W. of England, from which the ice moved in all directions. He pointed out that the contents of the drift appeared to be ignored; for although in the British sles the polar drift might have been pushed

out to sea by later glacial action, still it would only have been transferred a little further on; and had any such drift been deposited generally over the north of Europe, traces of it ought to be found along the south and east margins of the Scandinavian drift. He appealed to the vast scale of the changes of level to which this part of the earth's crust had been subjected, and especially to the shell-beds of Moel Tryfaen and Macclesfield, to prove that changes of level of at least 1400 feet had taken place since the Glacial period, and inquired whether elevation on even that scale would not recall glacial conditions over a large part of the area under notice. He again proposed to the Society a question which he had asked several years before:—what was the maximum pressure which ice would bear without becoming water or being crushed? and whether the consideration of this and the other conditions involved would lead us to assign a limit to the possible lateral extension and vertical thickness of an ice-sheet moving on a plain or uphill which would affect such speculations as that under discussion.

Mr. Mallet said, in reply to a question from the President, that experimental data were as yet wanting to enable a precise determination of the limit of distance to which an extraneous force could be transmitted through a prismatic mass of ice. The fundamental point of such an inquiry was—what is the modulus of cohesion of the most solid ice? A few experiments had been made, which showed that the height of this modulus could not exceed a few hundred feet. Let it be assumed, however, that it was as great as 5000 feet, or a mile. It was then obvious that a mass of ice, no matter how deep or wide, lying in a straight, smooth, frictionless valley, could not be pushed along by any extraneous force in the line of the valley through a distance of more than a single mile; for at that point the ice itself must crush, and the direct force cease to be transmitted further. This, of course, was far from being the whole of the question of the transmission of force through ice; for when and wherever crushing took place, a certain portion (though a small one) of the direct pressure was transmitted laterally by the crushed fragments, especially if mixed with water, simulating the quaquaversal properties of an imperfect liquid. For this to take place, however, in the direction of the length of the ice-filled valley supposed, the ice must be considerably more than a mile in vertical depth. These simple considerations were alone sufficient, he thought, to overthrow the notions which had been advanced by Prof. Ramsay and others as to the excavation of great valleys by the pushing of large masses of ice in the direction of their length. Mr. Mallet had had ample opportunities for several years as an engineer of observing the surface-features of Ireland, and indorsed the fact that almost everywhere the surfaces of the rocky skeleton, when hard enough or freshly uncovered, were found to be scratched, as were most of the boulders in the detritus above. But were these scratches necessarily evidence of the action of ice at all? he thought not. The general trend of the valley- and hill-ranges of Ireland was, as stated in the paper, N.E. and S.W.: but the production of those

valleys and anticlinals was obviously the work of the great formative forces by which the whole island had been forced up above the sea, by lateral pressure, squeezing the harder deposits into folds, and these carrying up upon their backs the deep covering of loose material which had lain upon them as sea-bottom. As the land emerged, this loose material was affected by tidal and wave-action, caused to slip and slide down all declivities, even very small ones, and, in doing so, scratched and furrowed the supporting surfaces of rock in a way that he believed it impossible to distinguish from the traces left by similar movements of masses of ice. And if this were so, as like phenomena must be as universal as the emergence of land was everywhere from beneath the sea, so it seemed to him that, so far as the evidences of scratching and polishing or denuding of rocks went, the glacial hypothesis was unnecessary. He admitted the scratching and transporting power of ice as a *vera causa* of some geological phenomena; but he believed that its effects had been enormously overrated, and that much had been attributed to its action which, when submitted to the test of "measure, number, and weight," in place of, as was the habit, perpetually dealing with "quality" only, would prove to be physical impossibilities. Thus the work capable of being done upon the ocean-bottom by the grounding of even the largest iceberg, could, when all the dynamic conditions were held in view, be proved to be extremely small. The general facts, as respects the direction of the striation or scratching of the rocks, as well as the direction of transport of boulders in the detritus above, were, for the whole surface of Ireland, that the scratches tended to lines down the great declivities, both laterally and longitudinally, but influenced by a great general trend from the west, and north, and south-west. The lines of boulder-travel had, on the whole, followed the same direction as the scratches. He could not, therefore, admit the views of the author as to the direction of these scratches being on the whole from north-east to south-west as representing the facts. Mr. Mallet referred to a case of a large subangular boulder found in deep clay by himself and Dr. Oldham, stopped in the very act of making an uncompleted groove, and under conditions that forbade any supposition of ice-action or any other source of movement but that of the quasi-fluid movement of the whole mass of clay carrying the boulder with it. He also pointed out that moraines, or masses dropped by ice, could not be distinguished generally from torrentially moved masses of clay, gravel, and rock, or from escars or eddy-bars formed by tidal-stream action, pointing out two cases, one in Wicklow, the other not far from Dublin, both pronounced by Agassiz to be indubitably moraines, but the former being manifestly a torrential bank, the other the effect of a tide-stream eddy when the plain of Dublin was still from 500 to 700 feet beneath the sea-surface.

Mr. Evans disputed Mr. Mallet's conclusions as to the propagation of motion through ice and the effects of grounding icebergs.

Mr. Tiddeman had examined a large portion of the western side of the north of England opposite to Ireland, but did not attribute

its glaciation to any general ice-cap radiating from the Pole. He thought that the ice-sheet was general over the northern part of the British Isles, and on a much larger scale than was usually admitted—and that one of the obstacles to its recognition was the later glaciation along the valleys, which was more conspicuous than the older traces, and another the difficulty which some people had in ignoring the present coast-line.

Mr. J. Clifton Ward stated that in the northern parts of the Lake district he had found that the direction of the ice-flow must have been mainly to the north.

The Author, in reply, remarked that in Greenland, whatever might theoretically be the case, ice is pushed for scores or hundreds of miles down into the sea, until it gets out of its depth, and eventually floats off as icebergs. He pointed out the correspondence of the main valleys of Ireland with glaciations on the surface of rocks from Scotland, and exhibited specimens and rubbings in illustration of various characters of weathering and wear from different natural causes.

February 5, 1873.

Thomas Checkley, Esq., 70 Lichfield Street, Walsall; John Mackenzie, Esq., Government Examiner of Coal-fields for New South Wales, Newcastle, N. S. W.; John Ollenshaw Middleton, Esq., 1 Ebenezer Terrace, Plumstead Common, S.E.; Walter Rowley, Esq., 74 Albion Street, Leeds; and George William Shrubsole, Esq., Victoria Road, Chester, were elected Fellows of the Society.

The following communication was read:—

The Oolites *of* Northamptonshire. By Samuel Sharp, Esq., F.S.A., F.G.S. Part II.

[Plates IX. & X.]

Introduction.

In accordance with the intimation given in my First Part of a Memoir upon the Oolites of Northamptonshire, I now beg to offer the Second Part of that Memoir.

The limited district of which I treated on the former occasion afforded facilities for its division into four areas, and for describing the beds and the order of their superposition in each; and thus, by a comparison of the beds and their sequence in the several areas, for arriving at a right understanding as to the geology of the whole district.

The field to which I now direct attention is much more extended, and is of a character that will not allow of such a systematic division. I hope, nevertheless, to be able to convey clearly that which I have to communicate.

The main feature of my First Part was the description and con-

sideration of that formation, commercially most valuable, and geologically most interesting, the Northampton Sand.

The main feature of my Second Part will be the description and consideration of a series of beds grouped by Mr. Judd under the name of the "Lincolnshire Limestone"—of less commercial value than the former, it is true, but scarcely of less geological interest.

My endeavour has been to trace, through the county in a north-easterly direction, to Stamford and somewhat beyond, the continuity of beds occurring in the Northampton district; to describe the Oolitic beds and their sequence at certain points within the area considered (involving the interposition of a new and important formation); to examine the geological characteristics of the districts round Stamford, and very briefly those of the eastern portion of the southern border of the county; and thus, while giving a general idea of the geology of the Northern Division of Northamptonshire, to help to establish the soundness of certain views not yet held to be altogether conclusive.

My data were gathered and this Memoir was drafted before I had the advantage of examining Mr. Judd's Geological Survey Map, Sheet 64; while, unfortunately for geological science, but perhaps as well for the object I have in view, that gentleman's Memoir has not yet become the property of the public.

It may perhaps by some be deemed superfluous in me to have produced this treatise at all, seeing that Mr. Judd's map is already in the hands of geologists, and that his Memoir will shortly be published.

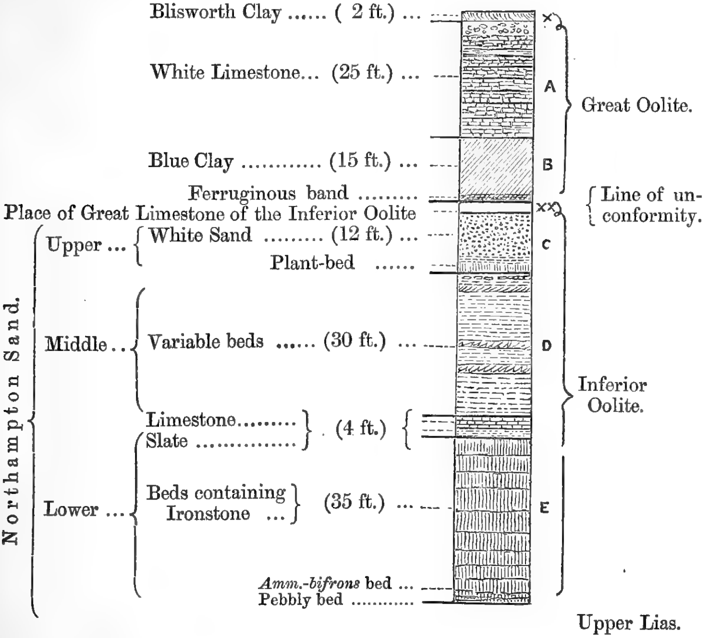
But some geologists still hesitate to accept the dictum that the beds of the Lincolnshire Limestone are Inferior Oolite; and, as Mr. Judd, after some years of close and systematic examination of those beds, and I, after a less systematic and exact although longer acquaintance with them, have independently come to the same conviction upon this point, I have thought that my second voice might not be without service, nor my local information without interest—especially as I have come armed from the beds to be discussed with an array of significant fossils, those once animate though now inanimate "oldest inhabitants," those silent yet eloquent witnesses to the truth of the conclusions at which we have arrived.

Before entering upon the task I have essayed to accomplish, as the Northampton district will, as it were, form my starting-point in tracing out the extension eastwards of the Oolitic beds of that district, it will be well to recall to notice the General Section given in my former communication.

It will be seen by this diagram that upon the clay of the Upper Lias are superimposed the series of beds of the Northampton Sand, having a maximum thickness of about 80 feet; which beds were divided by me (because of certain distinguishable characteristics) into "Lower," "Middle," and "Upper;" that upon the summit of the Northampton Sand occurs a plane of unconformity, indicated in the diagram as the "Place of the Great Limestone of the Inferior Oolite" (the Lincolnshire Limestone of Mr. Judd); and that above

this are three beds of the Great Oolite series, having a maximum thickness of 45 feet—the *lowest* consisting of clay having a persistent

Fig. 1.—*Diagram of General Section, showing the position of the Inferior Oolite Limestone and Divisions of Northampton Sand.*



ferruginous band at its base (which clay, containing wood, plants, and numerous bands with fresh-water shells, and exhibiting other estuarine characteristics, has been termed by Mr. Judd the "Upper Estuarine Series"); the *middle*, of a series of marly limestones; and the *uppermost*, of clay characterized by an abundance of *Ostrea subrugulosa*.

The Middle Division of the Northampton Sand was separated by me from the Lower Division (provisionally, as I stated) because of the intervention of a band of coarse Oolitic Limestone, and because of differences, throughout the district then treated of, in their mineral and stratigraphical characteristics.

To the north-east of Northampton, however, those differences are not so marked: for instance, over a considerable area, in the Lower Division, for ironstone is substituted an only slightly ferruginous limestone; and again, in other places, the Middle Division is quarried for ironstone, being more richly ferruginous than the Lower Division, while the Limestone band is frequently absent.

In contrast to the varying, and therefore uncertain, marks of distinction between the Lower and Middle Divisions of the North-

ampton Sand, those which define the separation of the Middle from the Upper Division everywhere obtain; for the presence of the sand-bed (generally with its characteristic vertical plant-markings, and designated by Mr. Judd the "Lower Estuarine Series") is observable wherever the Northampton Sand and higher beds are found in the same section.

It is a question, therefore, whether it would not be wise to abandon the hard line of separation between these Middle and Lower Divisions, and to class them together as the "Ferruginous" or marine beds of the Northampton Sand, retaining the distinction of the Upper Division of that formation under Mr. Judd's name of the "Lower Estuarine Series."

Exception has been made to the use of Mr. Judd's terms "Upper Estuarine" and "Lower Estuarine." I shall not enter upon this question: Mr. Judd is well able to maintain his own position. But, as these terms have been adopted in the maps of the Geological Survey, and will doubtless also be used in Mr. Judd's forthcoming Memoir, I have deemed it well, for the avoidance of confusion, to retain them in this treatise. For the same reason, I have adopted Mr. Judd's term of the "Great Oolite Clay" for the clay overlying the Great Oolite Limestone.

It is a fact worthy of notice that the two series of beds, the "Upper Estuarine" and the "Lower Estuarine,"—so widely separated in time and character, the one belonging to the period of the Great Oolite, and the other to that of the Inferior Oolite,—occur together in vertical juxtaposition in the neighbourhood of Northampton, throughout a large district including parts of both divisions of the county, and in Oxfordshire. In the latter county, the Upper Estuarine is traceable through to the Stonesfield Slate-bed; and the difficulty of separating the two Estuarines in Oxfordshire led to the conclusion arrived at, and published by the Geological Survey in 1860, that the Northampton Sand (few of its fossils being then known) was equivalent to the Stonesfield Slate.

An earlier conclusion prevalent among geologists (and perhaps still retained by some) was, that the Great Oolite limestone of the high grounds of the Northampton district, was identical with the limestone (the Lincolnshire Limestone) which occurs between Kettering and Stamford, and, characterizing the country about the latter town, extends on through Rutland and Lincolnshire into Yorkshire; that this Limestone was a member of the Great Oolite series; and that the calcareo-arenaceous slate of Collyweston and Easton, which bases this limestone, was the equivalent of the Stonesfield Slate of Oxfordshire: and this opinion has been maintained notwithstanding the discrepancy indicated by the very dissimilar fossil contents of the two formations and by the anomaly of their relative stratigraphical position.

I hope to be able to show the distinction between these two formations; to demonstrate, from the succession of beds at different points between Northampton and Stamford, and in the districts about Stamford, that, while the position of the Northampton Lime-

stone is that indicated in the diagram of the Northampton section, the true position of the Lincolnshire Limestone is below the Upper Estuarine series, and above the Lower Estuarine series of Mr. Judd's determination; and to prove, by palæontological evidence, that the former belongs to the Great Oolite, and the latter to the Inferior Oolite group of formations.

Northampton to Kettering *.

In proceeding from Northampton in a north-easterly direction to Kettering (14 miles) *en route* for Stamford, are passed over (variously, according to the frequent alternations of hill and dale) the several beds of the Northampton section. The Lincolnshire Limestone is not encountered in any place on this line, nor indeed is any peculiarity worthy of comment here, excepting that, at a few miles south of Kettering, a wide tract of the Great Oolite limestone (of which Kingsthorpe offers a typical example) is hidden by overlying beds of Glacial Drift. The occurrence of such Drift-beds is very frequent in the south-eastern and southern districts of Northamptonshire; but, as my purpose is to treat only of the Oolitic beds, I shall not again allude to these more recent deposits.

Before passing beyond Kettering to districts in which the great expanse of the Lincolnshire Limestone may be explored, I will revert for a moment to parts of the county, west of that town, in which that formation occurs.

Maidwell, Harrington, and Old.

At a distance of about 10 miles due north of Northampton, in the lordship of Maidwell, is a small patch of the Lincolnshire Limestone, having a spread of about a mile east and west, and half a mile north and south. This patch ranges about half a mile further west than the town of Northampton, and marks the extreme western extension of the area of the formation.

About a mile and a half due east of this, and separated from it by a north and south Liassic valley (through which the Blisworth and Harborough railway passes), is a much larger patch of this Limestone; which is the uppermost sub-surface rock throughout the greater part of the lordships of Harrington and Draughton.

Immediately beneath the Lincolnshire Limestone of these patches, as shown by the outcrop of the escarpment on either side of the valley, occur the Lower Estuarine and the Ferruginous beds of the Northampton Sand, without the intervention (be it particularly remarked) of the Upper Estuarine Clays, which, as B in the North-

* The route taken by the author in his descriptions and the areal disposition of the several beds he has described can be traced upon the maps of the Geological Survey—quarter-sheet LII. N.W., revised by Mr. Judd, and the admirable map sheet LXIV., by the same gentleman; but that route perhaps may be more easily followed by reference to the accompanying reproduced diagrammatic map (Pl. IX.), which was exhibited by the author on the occasion of the reading of this paper.

ampton Section, there separate the Great Oolite Limestone from those lower beds.

About three miles to the south of the Harrington area, and half a mile due east of the village of Old, is a small narrow strip of the Lincolnshire Limestone, only worthy of mention as being the most southerly point at which the presence of that Limestone has been detected.

Kettering.

At about a mile due east of Kettering, the eastern escarpment of the valley of the small river Ise presents this section:—

Great Oolite Limestone.
Upper Estuarine Series.
Lower Estuarine Series, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

This sequence (with the occasional superaddition of the Great Oolite Clay) is continued due east, right across the county to the Nene valley (a distance of 6 miles), and, with the further superadditions successively of Cornbrash, Kelloway Rock, and Oxford Clay, some three miles further still, to the boundary of Northamptonshire, and so on beyond, into Huntingdonshire.

Upon the outcrop of the same escarpment, at a point near Kettering Mill, and a very little north of the last-mentioned section, we find, as it were, the thin end of the wedge of the Lincolnshire Limestone coming in; and this section, and for the first time, is presented:—

Great Oolite Limestone.
Upper Estuarine Series.
LINCOLNSHIRE LIMESTONE (very thin).
Lower Estuarine Series, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

Upon the summit of the escarpment, upon the opposite or western side of the Ise valley (which here is about three quarters of a mile wide), and at about three quarters of a mile north-east of Kettering, the Lincolnshire Limestone, with a slightly increased thickness, again occurs, and at a little distance to the north is surmounted by the Upper Estuarine beds.

It is clear that at this point we cannot be very far off the original line of the thinning out of the Lincolnshire Limestone, and that we have touched upon the main continent (so to speak) of that formation, from which the Ise valley has here severed a portion of the southern margin; for, as the valley of the Ise trends northwards, the thin band exposed by the escarpment both thickens and spreads.

Leicestershire.

From the point of its first appearance near Kettering, the formation extends for six miles in a north-westerly direction towards Leicestershire; in which county is a small outlier between Medbourne and Holt.

Glendon, Cottingham, Rockingham, &c.

Diverging from a north-east course, we will follow for a time the range of the formation northwards. At Raven Wood, near Glendon (two miles from Kettering), are ancient quarries in the Lincolnshire Limestone; which here has a thickness of about 8 feet, and is disposed in the same number of courses, some of the upper of which are more or less Oolitic. Towards the bottom is a hard band containing numerous *Nerinæa cingenda*, Bronn, *N. triplicata*, Bronn, *Pinna cuneata*, Phil., *Serpula*, &c.

It was these quarries which, in 1869, I had the privilege of visiting (as stated in my First Part) in the company of Professor Ramsay, F.R.S., Mr. Etheridge, F.R.S., Mr. Howell, F.G.S., and Mr. Judd, F.G.S.; and here, upon the very threshold, as it were, of the formation, we found an abundance of fossils of sufficient significance to stamp the character of this Limestone, as being distinct from the Great Oolite Limestone of the Northampton district, and as being as certainly a member of the Inferior Oolite series.

Prominent among the fossils obtained and noted were:—

Gervillia acuta, *Sow.*
Lima proboscidea, *Sow.*
——, large sp. (allied to L. grandis, *Römer*)?
Pecten personatus, *Goldf.*
Pinna cuneata, *Phil.*

Cardium Buckmani, *Mor. & Lyc.*
Ceromya Bajociana, *d'Orb.*
Lucina despecta, *Phil.*, var. cardioides, *d'Arch.*
Myacites Scarburgensis, *Phil.*, sp.
Pholadomya fidicula, *Sow.*
Pholadomya Heraulti, *Ag.*
Tancredia axiniformis, *Phil.*
Trigonia hemisphærica, *Lycett.*

Natica Leckhamptonensis, *Lycett.*
Nerinæa cingenda, *Bronn.*
—— triplicata, *Bronn.*

Serpula socialis, *Goldf.*
—— sp.?

Acrosalenia Lycettii, *Wright.*
Pygaster semisulcatus, *Phil.*

Although the Upper Estuarine Clays are not seen in contact with the Lincolnshire Limestone in the Raven-Wood section, they immediately overlie it at a short distance eastwards.

At a short distance to the west is a deep railway-cutting in the Lower Estuarine Sands; and at its north end, on either side, are shallow quarries in the Ferruginous beds of the Northampton Sand. So that the circumstances of the locality offer facilities for ascertaining certainly the vertical sequence of beds there; which is represented in this gathered section, drawn from data taken by Mr. Etheridge on the spot:—

Section near Glendon Railway-cutting.

		ft.	in.	ft.	in.
Lincolnshire Limestone				8	0
Northampton Sand.	Lower Estuarine Sands:—				
	a. Brown Sand	2	0		
	b. Plant-bed, with vertical markings	1	6		
	c. White Sands	8	0		
				11	6
	Ferruginous beds			10	0
Upper Lias Clay.					

The ironstone here is very fossiliferous in bands; the fossils noted presenting the same *facies* as those obtained from the Duston ironstone quarries.

Fossils from the Ferruginous Beds at Glendon.

Avicula Münsteri, *Goldf.*
Gervillia acuta, *Sow.*
—— lata, *Phil.*
Hinnites abjectus, *Phil.* sp.
—— velatus, *Goldf.* sp.
Lima, large sp. (allied to L. grandis, *Römer*)?
Pecten personatus, *Goldf.*
Pinna cuneata, *Phil.*
Pteroperna, sp.?

——
Astarte elegans, *Sow.*
Cardium Buckmani, *Mor. & Lyc.*
Corbicella Bathonica, *Mor. & Lyc.*
Trigonia compta, *Lycett.*
—— Phillipsii, *Mor. & Lyc.*
—— Sharpiana, *Lycett.*
—— V-costata, *Lycett.*
Unicardium, sp.?

Passing northwards, at Barford Bridge, about a mile from Raven Wood, we again cross the meandering valley of the Ise, and again encounter, on the northern escarpment, the same decisive sequence of beds as that near Kettering:—

Great Oolite Limestone.
Upper Estuarine Series.
LINCOLNSHIRE LIMESTONE.
Lower Estuarine Series, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

For two miles further north, we pass, upon the high ground, over the Great Oolite Limestone, and, with a slight incline, down a narrow outcrop of the Upper Estuarine Clays, and again on to the Lincolnshire Limestone. This thickens northwards; so that, at Cottingham, is a section which exposes a thickness (and this not the whole thickness) of 25 feet.

Low down in the section at Cottingham, and in the same position in other sections near Rockingham, is a band containing plants, mostly ferns, among which may be detected fronds in fructification of *Pecopteris polypodioides*, Lindley; which zone also occurs at Collyweston and Easton, near Wansford, and elsewhere, in the same position.

In the Park of Rockingham Castle* (the high ridge of which is nearly 250 feet above, and overlooks to the north, the valley of the river Welland, and commands an extensive view into the counties of Leicester and Rutland), I have noted the following succession of beds:—

	ft. in.	ft. in.
Lincolnshire Limestone—		
Coarse oolitic beds	10 0	
Marly beds (only partly exposed)........................	5 0	
	——	15 0
Northampton Sand—		
Lower Estuarine Sands, with argillaceous bands and patches, and vertical plants	13 0	
Ferruginous beds...	14 0	
	——	27 0
Upper Lias Clay.		

* At the western extremity of the line of my horizontal section. See Pl. X. fig. 2.

WEEKLY and GEDDINGTON.

The road from Kettering to Stamford skirts the valley of the Ise upon its north-western escarpment; which presents, beyond Weekly, the same succession of beds as before, but which in the interval have been somewhat disturbed by a small fault, having a south-west and north-east direction:—

Great Oolite Limestone.
Upper Estuarine.
LINCOLNSHIRE LIMESTONE.
Lower Estuarine, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

A little further on, at a short distance south of Geddington, is a quarry in the Lincolnshire Limestone *. The Upper Estuarine Clay is just seen coming in at the top; below this, is a thickness of 15 feet of Lincolnshire Limestone (the lowest bed but one consisting of the hard *Nerinæa* zone, as at Glendon); and at bottom, a reddish sand, representing the Lower Estuarine Series.

Section at the South Geddington Quarry.

	ft.	in.
1. Upper Estuarine Clay (just apparent).		
2. Lincolnshire Limestone—		
a. Marly oolite, in thin bands, and much shattered, about ...	6	0
b. Soft marly limestone, containing few shells—burnt for lime	3	0
c. Hard sub-crystalline bed, blue-hearted, in three or four courses, containing numerous *Nerinæa cingenda, N. triplicata,* &c.—the fossils standing out in relief upon the joint surfaces, from the action of water charged with carbonic acid	3	0
d. Shaly soft bed—"very rotten"—about	3	0
3. Reddish sand—Lower Estuarine.		

The village of Geddington is situated upon the Upper Lias Clay of the Ise valley; and is celebrated for its beautiful Cross, the most elegant of the three crosses which remain of the twelve erected in A.D. 1290, by Edward I., in memory of his Queen, Eleanor of Castile. It was built over a spring of ancient celebrity. Its material is Barnack Rag, and it is nearly as perfect as when erected, never having been restored.

Just north of Geddington, is Rippen's quarry in the Lincolnshire Limestone. The section is of the same character as that in the quarry south of Geddington; but the limestone beds have thickened to about 20 feet.

Fossils found in the two quarries:—

Hinnites abjectus, *Phil.* sp.
Pecten personatus, *Goldf.*
Pinna cuneata, *Phil.*
Pteroperna pygmæa, *Mor. & Lyc.*
Modiola Sowerbyana, *d'Orb.*
Trigonia hemisphærica, *Lycett.*
Unicardium impressum, *Mor. & Lyc.*
Natica Leckhamptonensis, *Lycett.*
Nerinæa cingenda, *Bronn.*
—— triplicata, *Bronn.*
Pygaster semisulcatus, *Phil.* ("petrified mushrooms" of the pitmen).
Pecopteris polypodioides, *Lindley.*

* Up to this point, the Geological Survey Map, Quarter-sheet LII., N.W., revised by Mr. Judd, has served to supplement my personal observations.

Ascending the escarpment north of Geddington, we again pass over the same almost inevitable sequence:—

Great Oolite Limestone.
Upper Estuarine Series.
LINCOLNSHIRE LIMESTONE.
Lower Estuarine, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

In the discussion after the reading of my First Part, Professor Morris said he "had found a difficulty in reconciling the phenomena of the eastern and western Oolitic areas, but considered that the key of the arrangement was to be sought in the district between Northampton and Stamford."

I agreed with Professor Morris in the opinion expressed in the latter part of his remarks; but I would submit that "*the key*" has been abundantly found, in the sections already noted, which display such a remarkably uniform and significant sequence of beds; which sequence occurs over and over again upon unnumbered escarpments throughout the area of the Lincolnshire Limestone.

Little Oakley and Stanion.

From Geddington, we pass over the Great Oolite Limestone to Little Oakley; between which village and Stanion, a valley is traversed which exhibits the usual series of beds, but complicated by the intricate intersection of several small crossing faults.

Weldon.

About four miles north-east of Geddington, are the Weldon quarries, whence is obtained the widely known Weldon freestone. The extent of the area which has been broken up into "Hills and Holes" (much of it planted over with trees of considerable growth) bears testimony to the antiquity of the excavations, and to the quantity of stone which has been raised. This freestone is a rather coarse-grained Oolite of a ruddy hue, having frequently a glittering fracture. When a disengaged block is struck with a hammer, "it rings like a bell" (to use a quarryman's expression); a peculiarity which more or less characterizes the good freestones of this formation. It was much used in ancient times in the erection of churches and other prominent buildings throughout a very considerable district.

Mr. Judd obtained a fine series of fossils from the Weldon quarries, a list of which will be published in his Memoir. I only succeeded in noting the following:—

Pecten articulatus, *Schloth.*
Rhynchonella varians, *Schloth.*
Monodonta?
Nerinæa cingenda, *Bronn.*
—— triplicata, *Bronn.*
Phasianella elegans, *Mor. & Lyc.*
—— parvula, *Mor. & Lyc.*
—— Pontonis, *Lycett.*
Acrosalenia (spine).

The following is the section of the quarry at this time being worked; with quarrymen's terms:—

	ft. in.	ft. in.
1. Baring, consisting of— *a.* Surface Soil, *b.* Boulder-clay, *c.* Upper Estuarine Clay	10 0 to	12 0
2. "Top Fine Stone"—pink oolitic freestone, having numerous comminuted but few perfect shells on the bedding surfaces: extracted in large blocks............	1 6 to	2 0
3. "Rag"—a coarse red shelly stone, variegated horizontally, but not splitting in the planes of variegation; very soft in the bed, but hardening upon exposure; and very full of small shells. This stone, although good and durable for some purposes, is for the most part rejected, and buried with the infilling	2 0 to	2 6
4. Marly limestone, blue-hearted, and sometimes hard: it would make good lime, but is thrown away.........	2 0 to	2 6
5. "Lower Fine Stone"—also of a pink hue, very oolitic in grain, free in working, cut out in large blocks, and containing a few fossils		2 6
6. "Bottom Fine Stone"—a finer, whiter, and very oolitic freestone; the best stone of the section, and also raised in large blocks............		2 6
7. Below these beds, as shown by a trial-hole, are several other strata; marly, sometimes shaly, and not worth quarrying; and having an aggregate thickness exceeding		14 0

About half a mile due north of the last quarry, is a shallow lime- and road-stone pit, exposing a section of from 6 to 8 feet of marly limestone, in very thin courses, but yielding no fossils. These are probably the continuation of some of the lower and unworked beds of the freestone quarry.

Weldon is about midway of my horizontal section between the Welland and the Nene valleys (Pl. IX. fig. 3); which has Rockingham at its western and Oundle at its eastern extremity, and to which I shall further allude when I come to describe the succession of beds at the last-named town. Although the Lincolnshire Limestone attains at Weldon to a thickness exceeding 25 feet, its south-western boundary cannot be very far removed; as it is nowhere found in directions due east, south-east, or south, at a greater distance than three miles. Its original margin on this side, however, may have been diminished by denudation prior to the deposition of the overlying beds.

Kirby Old Slate Quarries.

Two miles due north of Weldon are the Kirby "Old Slate Quarries." These are not now worked, and no section is exposed. From such portions as I could find *in situ*, it would appear that the upper beds are oolitic, and the lower marly limestone. This arrangement seems very frequent in the Northamptonshire districts of the formation (as long since noticed by Professor Morris), although by no means uniformly prevalent; and it is probably merely the result of varying accidental and local conditions.

The marly beds contained:—

Gervillia acuta, *Sow.*
Pecten, large (probably lens, *Sow.*, or new sp.?)
Ceromya Bajociana, *d'Orb.*? }
—— similis, *Lycett*? }
Modiola Sowerbyana, *d'Orb.*
Pholadomya, sp.?
Trigonia Phillipsii, *Mor. & Lyc.*

The hard *Nerinæa* zone was present, but I could not detect the presence of slate. At about half a mile south-west, however, near to Deene Lodge, are more modern pits, where slate is quarried; and these present the extreme south-western point at which slate equivalent to the Collyweston Slate has been found.

Deene.

At Deene, two miles and a half north-east of Weldon, is a large stone- and brick-pit; which exhibits, under four feet of sand, soil, and rubble, about six feet of the Lincolnshire Limestone, having at its base three feet of a bed with "potlids," representing the Collyweston Slate-bed: below this, the Lower Estuarine occurs, of considerable thickness and very different in character from the same bed in the Northampton district—reddish sand, four feet; grey sand, with vertical plant-markings, three feet; a very dark chocolate almost black shaly clay, in very thin layers, five or six feet; beneath this, slate-coloured clay, containing a zone of iron-pyrites: then several feet of the ferruginous beds of the Northampton Sand; and below all, the Upper Lias Clay.

Upon my first examination of this pit, I was uncertain as to whether the Ferruginous Beds of the Northampton Sand were not wanting here, and as to whether the clays below the vertical plant-bed (as they yielded no fossils as an indication) were Lower Estuarine or Upper Lias. Mr. Judd has told me that he encountered the same difficulty in the first instance; but that, fortunately, a well was sunk, which passed through these clays for 10 feet, pierced several feet in thickness of the Ferruginous Beds of the Northampton Sand, and dipped into the Upper Lias Clay below.

Detailed Section at Deene Brick-pit.

		ft. in.	ft. in.
	1. Baring—soil, sand, and rubbly stone		4 0
Lincolnshire Limestone.	2. Marly limestone, of various degrees of hardness, in courses about 6 inches in thickness		1 6
	3. Sandy bed, containing rounded calcareous concretions	1 6 to	2 0
	4. Hard subcrystalline limestone, sometimes blue-hearted, containing numerous *Nerinææ*	2 6 to	3 0
	5. Sand, with "potlids," the latter very hard—Collyweston Slate	3 0 to	3 6
Northampton Sand.	6. Reddish Sand		4 0
	7. Grey Sands and Clay, with vertical plant-markings		3 0
	8. Dark chocolate, very shaly, thinly laminated clay, about		6 0
	9. Slate-coloured Clay, with masses of iron-pyrites, about		4 0
	10. Ferruginous Beds (several feet).		
	11. Upper Lias Clay.		

Fossils noted at Deene.

Cardium Buckmani, *Mor. & Lyc.*	Trigonia Sharpiana (?), *Lycett.*
Ceromya Bajociana, *d'Orb.*	Nerinæa cingenda, *Bronn.*
Goniomya V-scripta, *Sow.*	—— triplicata, *Bronn.*
Lucina Wrightii, *Oppel.*	Serpula socialis, *Goldf.*
Modiola Sowerbyana, *d'Orb.*	Coral, sp.?
Perna, sp.?	Coniferous wood (large pieces of drift).
Pholadomya sp.?	Ferns (Pecopteris polypodioides, *Lindley*), &c.
Trigonia Phillipsii, *Mor. & Lyc.*	

Deene to Collyweston.

As between Northampton and Kettering the road passes over the Great Oolite Limestone and subjacent beds, varied by the occurrence and recurrence of hill and dale, so between Deene and Collyweston, passing through the villages of Bulwick and Duddington, the road, with a like variation, traverses the Lincolnshire Limestone for a distance of seven miles. No peculiarity worthy of notice occurs on this line; and I will, therefore, diverge, at Fineshade, for the sake of noticing a rather remarkable section at Wakerley, one mile to the west, and quarries, notable for the fossils they have yielded, at Morcot, two miles beyond.

Wakerley.

The section at Wakerley exposes a series of beds in the Lincolnshire Limestone, having an aggregate thickness of about 30 feet; the whole of which, from the top to the bottom, are exceedingly (some coarsely) oolitic; and several exhibit false-bedding. Five or six courses of the lower part of the section are like the "Rag" at Weldon, and full of imperfectly preserved shells. I obtained from the "Rag" beds, *Pseudodiadema depressa*, Ag., and a fine spine of *Cidaris Fowleri*, Wright*.

Details of Section of Lincolnshire Limestone at Wakerley.

	ft. in.	ft. in.
1. Rubbly oolite	3 0 to	3 6
2. Oolitic limestone, in three courses	3 6 to	4 0
3. The like, false-bedded, very inclined		4 0
4. The like, but in horizontal layers	3 0 to	3 6
5. The like, false-bedded		4 0
6. The like, horizontal		3 0
7. Very coarse oolite		1 0
8. "Rag" bed (like the "Rag" at Weldon), full of shells, chiefly minute, imperfectly preserved—in four to six courses, some very false-bedded	6 0 to	8 0

Between the nearly adjoining villages of Wakerley and Barrowden, flows, over the Upper Lias, the river Welland; which, throughout almost the whole of the southern boundary of Rutland, serves as the line of demarcation between that county and Northamptonshire.

* Mr. Judd, I believe, has obtained a large number of characteristic Inferior Oolite fossils from this quarry.

Morcot.

At Morcot, in Rutland, two quarries are now being worked: these are at different elevations upon the escarpment (facing north-west) of the small river Chater. It is probable that the lower beds of the upper quarry are identical with the upper beds of the lower quarry. It will be necessary, therefore, in order to understand the whole section, to combine the two; and this view is confirmed by the fact that, while beds having blue cores are absent in the upper quarry, such beds occur towards the bottom of the section in the lower one.

The total thickness of the beds at the higher level is about 18 feet, and that of the beds at the lower level about 17 feet: but these figures do not indicate the whole thickness of the Lincolnshire Limestone at Morcot; for the presence of beds of the same formation is to be detected still higher on the escarpment than the summit of the higher quarry, and below the lowest beds of the lower quarry occur slate beds (not now exposed) from which characteristic fossils have been obtained: so that it is probable that the Lincolnshire Limestone at this place has a thickness of quite 60 feet.

The Morcot sections display the local variability of the Lincolnshire Limestone; for, while at Wakerley, only two miles distant, the beds from top to bottom are essentially oolitic, at Morcot, the sections are marked by the almost entire absence of the oolitic character, there being only one bed, of a foot in thickness, which is oolitic at all, notwithstanding that the numerous beds differ greatly in other respects, consisting of harder and softer bands of marly limestone in various alternations.

Detailed Sections.—*Upper Quarry, Morcot.*

	ft. in.	ft. in.
1. "Rammel"—broken limestone	3 0 to	3 6
2. Soft calcareous bed, used for burning only		3 0
3. Brownish sand, containing calcareous masses—"used for building"		3 6
4. Compact limestone		1 0
5. *Oolitic* "Wallstone"		1 0
6. Hard compact limestone, in two courses		1 0
7. Close marly limestone, sometimes rather crystalline		9
8. Hard marly limestone, thickness uncertain.		

Lower Quarry, Morcot.

	ft. in.	ft. in.
1. "Rammel"—broken limestone		3 0
2. Shattered limestone, in thin layers, becoming less broken and thicker in the layers towards the bottom of the bed		6 0
3. Soft shaly bed, with plants	2 0 to	3 0
4. Compact marly limestone, in two courses—with *Hinnites abjectus*, Phil.		2 0
5. Very hard blue-hearted limestone	9 to	1 0
6. Hard limestone, more or less crystalline, sometimes blue-hearted, in two courses		3 0

Fossils from Lincolnshire Limestone, Morcot.

Gervillia radians, *Mor. & Lyc.**
Hinnites abjectus, *Phil.*
Inoceramus obliquus, *Mor. & Lyc.*
Lima cardiiformis, *Sow.*
Ostrea (young).
Pecten lens, *Sow.*
Pinna cancellata, *Bean.*
—— cuneata, *Phil.*

Ceromya Bajociana, *d'Orb.*
—— concentrica, *Sow.*
——, sp.?
Lucina Bellona, *d'Orb.*
—— Wrightii, *Oppel.*
Modiola Sowerbyana, *d'Orb.*
—— sublævis (?), *Sow.*
Pholadomya Dewalquea, *Lycett* (syn. of media of *Dewalque* and *Chapuis*).
—— ovulum, *Ag.*
——, sp.?
Tellina, sp.?
Trigonia compta, *Lycett.*
Unicardium depressum, *Phil.*, sp.

Terebratula globata, *Sow.*

Natica adducta, *Phil.*
—— Leckhamptonensis, *Lycett.*
——, sp.?
Pterocera Bentleyi, *Mor. & Lyc.*†

Serpula, sp.?

Acrosalenia Lycettii, *Wright.*
Cidaris Fowleri, *Wright.*
Pygaster semisulcatus, *Phil.*
Stomechinus germinans, *Phil.*

Ferns:—Pecopteris polypodioides, *Lindley*, &c.

To the south-east of Morcot, and to a high level, stretches the comparatively barren tract of Barrowden Field; in crossing which by the road to Tixover and Duddington, are passed over in succession (above the Lincolnshire Limestone)—the Upper Estuarine Series, the Great Oolite Limestone, the Great Oolite Clay, and, at the highest ground, a thin capping of CORNBRASH.

LUFFENHAM.

Two miles north-east of Morcot, upon the Uppingham and Stamford road, near to the Luffenham Railway Station, is a quarry the limestone beds of which answer to those of the lower Morcot quarry, and yield some similar fossils.

KETTON.

Three miles further in the same direction, and beyond the village of Ketton, are the quarries whence is obtained the far-famed KETTON FREESTONE. This is the most excellent in quality of any freestone now obtainable throughout the entire area of the Lincolnshire Limestone.

When I refer to the church of St. Dunstan in Fleet-street, which is built of this stone, and point to the unimpaired condition of its exterior surfaces, after many years' exposure to the disintegrating action of the London atmosphere, I need say nothing of the durability of the Ketton freestone, even when exposed to unfavourable conditions.

It is a matter of observation that the "Ketton" freestone is of better quality when obtained from beneath a thick bed of clay, than

* Nearly allied to *Gervillia Hartmanni*, Goldf., a not unfrequent fossil in the Duston ironstone beds.

† Collected by Mr. Judd. See notice of this beautiful form in description of Fossils of Collyweston Slate Beds—forward, page 247.

when occurring nearer to the surface; and it is perhaps worthy of notice that, not only Ketton stone, but all stone having its origin in sedimentary deposition, is more enduring when in buildings it is placed in the same horizontal position which it occupied in its natural bed. If stone is placed in buildings with its planes of stratification in a vertical position, the crush of superincumbent weight will frequently split it; and this not occurring, weather action will probably scale the surface. Such phases of dilapidation are constantly to be observed in stone window mullions; in which, for the sake of economy of time and material, the naturally horizontal stratigraphical planes of the stone are perverted into a vertical position.

The Ketton quarries exhibit an immense area of broken ground; and, as no attempt has been made to level or restore the surface after excavation, it is left in a perfectly useless condition—offering a very unfavourable contrast to the admirable practice which obtains in some parts of Northamptonshire, of restoring, after quarrying, the surface to a state as good as, and sometimes, for the purposes of cultivation, even better than, before.

There are two places, not widely separated, where the Ketton stone is quarried at this time—one an old working, called "the Deeps," from which comparatively only a small quantity of stone is obtained, but presenting the deeper section; the other, more recently opened, presenting a less deep but very lengthened section. The latter is divided into several holdings or proprietorships; a large number of men are employed; and a great quantity of stone is raised.

In the "Deeps," the freestone underlies about 17 feet of the Upper Estuarine Clays, divided into three beds of various character, colour, and thickness, based by the usual ferruginous band. These clays contain shelly seams; some of which are characterized by the presence of the small peculiar rostrated bivalve *Neæra Ibbetsoni*, Morris, and others by *Cyrena*, &c. Three beds of stone are exposed, having an aggregate thickness of 11 feet: these consist of—a coarse red Oolite, good Ketton freestone, and a very hard, sometimes crystalline and blue-hearted, "Rag" stone.

Details of Section at "The Deeps," Ketton.

	ft. in.	ft. in.
1. Upper Estuarine beds—		
a. Grey clay	3 0	
b. White clay	5 0	
c. Variegated clay	8 0	
d. Ferruginous band	0 9	
		16 9
2. Oolitic beds, Lincolnshire Limestone—		
a. Coarse red oolite	2 6	
b. "Freestone"—good Ketton Stone, *Lima proboscidea*, frequent	3 6	
c. "Rag" stone—sometimes blue-hearted, very glistening on fracture, in several courses	5 0	
		11 0

Many years ago, in an adjacent working, I obtained during one of my pleasantly remembered excursions in the company of Prof. Morris, a fragment of the upper surface of the red oolitic bed of this section, which had been profusely perforated by a small boring bivalve.

In the Ferruginous beds of the Northampton Sand, casts of the crypts of *Lithodomus inclusus*, Phil., generally including the shell, are very abundant, and sometimes large, but are always found associated with masses of coral. On the other hand, in the limestones of the Great Oolite, casts of the crypts of *Pholas* occur, not so associated. As no coral has been found in connexion with these borings, I am disposed to conclude that they are the work of *Pholas* rather than of *Lithodomus*. At any rate, I would agree with the conclusion arrived at by Prof. Morris, as stated in his admirable article in the 'Geological Magazine' for March, 1869, that these perforations "clearly indicate a period of arrested deposition in this old sea-bed; during which these mollusks lived and inhabited the surface of the subjacent rock, already partly consolidated."

The newer and larger excavations at Ketton are near the base of an escarpment facing north-east. The section presents a thickness of beds of some 20 to 23 feet. The upper portion, to the depth of about 15 feet, consists of the clays of the Upper Estuarine Series, in three beds (as in the last section), viz. grey clay, whitish clay (with vertical yellow markings, as of root perforations), and a very compressed, thinly-laminated, and somewhat bituminous clay, intercalated with thin seams of brown and white sand, and having the ferruginous band at the base. The lower portion consists of Lincolnshire Limestone; the upper two beds of which, having together a thickness of from 5 to 6 feet, are oolitic freestone. The upper bed, being red, coarse, and perishable, and known as "Flesh" or "Crash" by the quarrymen, is rejected: the lower bed is the celebrated Ketton freestone. Beneath the freestone, is a shelly "Rag" bed, not worked, but probably about 4 feet in thickness; and underlying this, is a harder oolitic limestone having a glistening fracture, which also is not worked, and its thickness is uncertain. I have obtained from this bed, *Cypricardia Bathonica*, d'Orb., and *Pholadomya fidicula*, Sow.

As the works proceed, and an advance is made into the mass of the hill, the section will deepen by an accession to the thickness of the Upper Estuarine clays. The high ground above has a capping of Great Oolite limestone.

Details of Section at the Newer Excavations, Ketton.

1. Upper Estuarine Series—

	ft. in.	ft. in.
a. Grey clay	3 6	
b. Whitish clay, with yellow vertical markings, like root perforations	4 6	
c. Very compressed and somewhat bituminous clay, in very thin layers, intercalated with thin seams		

	ft. in.	ft. in.
of brown and white sand, and containing shelly bands	7 0	
d. Ferruginous band	0 6	
	——	15 6
2. Lincolnshire Limestone—		
a. Coarse and very oolitic red stone, sometimes perforated on the upper bedding surface by *Pholas* borings—the "Flesh" or "Crash" of the quarrymen—crumbles upon exposure to frost, and is not quarried for "freestone"—varying in thickness up to	2 6	
b. "Freestone" bed—the celebrated Ketton stone, very oolitic, and freely worked, hardens upon exposure	3 0	
c. "Rag" stone—pisolitic bed, about	4 0	
d. Harder "Freestone"—more siliceous, presenting a glistening fracture, not worked, and thickness not ascertained	—	
	——	9 6

Fossils from the Upper Estuarine Series, Ketton.

Modiola imbricata, *Sow.*
Neæra Ibbetsoni, *Morris.*
Cyrena, sp.?
&c.

Fossils from the Lincolnshire Limestone Beds, Ketton.

Lima bellula, *Mor. & Lyc.*
—— cardiiformis, *Sow.*
—— proboscidea, *Sow.*
—— Pontonis, *Lycett.*
——, large sp. (allied to L. grandis, *Römer*)?
Pecten aratus, *Waagen.*
——, sp.?
——, sp.?
Pteroperna plana, *Mor. & Lyc.*

Cardium Buckmani, *Mor. & Lyc.*
Ceromya, sp.?
Lucina Wrightii, *Oppel.*
Modiola imbricata, *Sow.*
Myacites decurtata, *Phil.*
——, sp.?
Pholadomya fidicula, *Sow.*
Pholas, sp.?

Terebratula fimbria, *Sow.**
—— globata, *Sow.*
—— sub-maxillata, *Sow.*
—— perovalis, *Sow.*

Natica Leckhamptonensis, *Lycett.*

Belemnites Bessinus (?), *d'Orb.*

Acrosalenia Lycettii, *Wright.*
Echinobrissus clunicularis, *Lhwyd.*
Pseudodiadema depressum, *Agassiz.*

Montlivaltia Delabechii, *Edw. & Haime.*

Strophodus magnus, *Ag.* (palates).

Ketton, to Geeston and Collyweston.

Proceeding southwards, through Ketton, we pass its very beautiful church, portions of which are of the Norman, Semi-Norman, Early English, and Early Decorated styles (dating respectively in the 12th, 13th, and 14th centuries), all unimpaired, and all built of the neighbouring "Barnack Rag," the famous church building-stone of a wide district in those early times.

We then cross upon the Upper Lias the river Chater, and ascend to the so-called Ketton station, which is in the hamlet of Geeston.

* *Terebratula fimbria* occurs also at Denton, Ponton, and Barnack, and Mr. Judd has met with it in the same beds near Lincoln.

A deep railway-cutting here trenches the Lincolnshire Limestone; the beds of which are much inclined and disrupted, having been traversed by a fault. The section exhibits no peculiarity: the upper beds, as usual, are oolitic, the lower more or less marly and crystalline. The Slate bed occurs near the bottom, overlying the Lower Estuarine and the Ferruginous beds of the Northampton Sand. Prof. Morris, in his "Notice," published in the 'Transactions of the British Association' for 1847, describes the section in this cutting as exposed during the formation of the railway, as follows:—

	ft.	in.
"Rubbly oolite in shivers	3	0
Compact marly limestone—*Nerinæa* and *Ferns*	2	6
Marly rock, very fossiliferous—*Nerinæa*, *Modiola plicata*, *Ferns*, and *Isocardia* (*Ceromya*) *concentrica*, *Pinna*, *Arca*	2	0
Sandy rock, with *Lima*, &c.	2	0
Crystalline ragstone, with *Nerinæa* and patches of plants	3	0
Compact crystalline oolitic ragstone	8	0
Concretionary bed	2	6
Slate beds	3	0
Greenish clay	2	0
Ferruginous sand of inferior oolite at bottom."		

Proceeding southwards, we cross the Welland valley (again upon the Upper Lias) once more into Northamptonshire; and, in ascending the hill to Collyweston, see cropping out in succession upon the excavated road-side the Ferruginous beds of the Northampton Sand, the Lower Estuarine Sands, the Collyweston Slate, and some Limestone bands above.

Collyweston.

The Collyweston Slate quarries commence immediately east of the village, and extend continuously for more than a mile north-east into the parish of Easton. It is known that they have been worked for 350 years, and possibly for a much longer period. The slate is of a fine-grained calcareo-arenaceous material, and occurs at the base of the Lincolnshire Limestone, in a thin band; the under surface of which frequently assumes the form of flattened hemispherical masses (like the "potlids" and "whinstones" of Stonesfield), which with the convex surfaces downwards, repose upon the white sand of the Lower Estuarine Series: in hollows upon the surface of which it would seem as if they had been moulded.

The "Slate," when first raised, is a very hard and solid stone, frequently blue-hearted; but, upon exposure to moisture and to frost, it becomes fissile, and its fine laminæ readily split into the "slates" so widely known and locally used for so long a period. It is remarkable, however, that, after exposure, if the frost has not been of sufficient intensity to split the stone, it becomes impervious to frost-action afterwards. I was informed by the pitmen during a recent visit, that only one night's effective frost occurred during the previous winter (1871–72); that, in consequence, an immense quantity of slate stone which had been raised was not available for

conversion into slates; and that as a result many pits for the present had been thrown out of work.

The superincumbent beds at Collyweston and Easton have an aggregate thickness varying according to situation from 15 to 25 feet, and present lithological and sectional peculiarities not to be found in any sections in the Lincolnshire Limestone which I have elsewhere had the opportunity of examining; but which (as Mr. Judd informs me) are not very unlike those which characterize some sections in Lincolnshire.

From the number and great extent of the slate quarries, it would be expected that some variations in the sections would be exhibited. This, to a certain extent, is the case—as will be found upon a comparison, one with another, of a section taken by Prof. Morris prior to 1847, and published in his "Notice" in the 'Transactions of the British Association' for that year, one noted by me several years ago, and others taken by me during the recent autumn. Beds present in some sections are wanting or have changed their character in others; and beds traceable through several sections are thicker or thinner according to locality.

Section taken at Collyweston by Professor Morris prior to 1847.

	ft.	in.
1. Compact oolite in shivers	7	0
2. Oolitic freestone	2	6
3. Marly oolite	2	6
"Cream-coloured marly limestone, containing zones of shells of which the *Nerinæa cingenda* and other species, *Lucina*, *Pholadomya*, *Modiola plicata*, are abundant; with patches of fragments of ferns (*Pecopteris polypodioides*) and other plants (*Zamites*), not occurring in regular layers."		
4. Concretionary sand bed ("beds of sand and sand-rock")	1	6
5. Compact crystalline ragstone ("with *Nerinæa* and *Ferns*")	1	6
6. Brown rubbly incoherent sand, with concretions	2	0
"A concretionary bed of sand, with irregular cylindrical ramose bodies of sandstone, resembling fucoid stems."		
7. Slate beds—"Calcareo-siliceous beds, grey and brown."		

Former Section taken by S. S.

	ft.	in.		ft.	in.
1. Flaggy limestone, slightly ferruginous, and more arenaceous and siliceous than the ordinary Lincolnshire Limestone of the district. [This bed represents bed 3 of Professor Morris's section.]	3	0	to	4	0
2. Sand bed—somewhat ferruginous, and containing fantastic concretionary masses. [4 of Morris.]	3	0	to	4	0
3. Flaggy limestone—sometimes blue-hearted. [5 of Morris.]	3	0	to	4	0
4. Peculiar laminated bed, made up of alternate layers of sand and calcareous sandstone, each about half an inch in thickness; these are from 40 to 50 in number, and the edges of the sandstone layers stand out in relief upon the surface of the bed. In one section this bed presents the most remarkable wavy distortion. [6 of Morris?]	2	0	to	2	6
5. Hard compact blue-hearted limestone in courses	3	0	to	5	0

6. Slate bed—the lower surface moulded into flattened hemispherical forms. [These beds (5 & 6) represent the slate beds (7) of Morris.]
7. Sand (Lower Estuarine) } Northampton Sand.
8. Ferruginous beds }

During my recent visit, I carefully took notes of two sections somewhat widely separated, adopting for the several beds the familiar names given them by the quarrymen; and I will here parenthetically suggest that it would be desirable generally to adopt the plan of taking such names, as these would serve for the purposes of identification and comparison upon future visits of geologists, and in after times, even though the exact sections described may have long since disappeared. These two sections so nearly tallied in every respect, except as to thickness, that one table will serve to describe both.

Section of Slate Quarries, Collyweston, Sept. 1872, with Quarrymen's Terms.

	Perkins's Pit.	Hill's Pit.
	ft. in. ft. in.	ft. in. ft. in.
1. Broken stone, in thin layers (*Natica Leckhamptonensis*, Lycett)	1 0 to 2 0	2 0 to 3 0
2. "Red Cale"—very oolitic stone, like bad Ketton freestone, in thin courses. [These beds together represent beds 1 & 2 of Professor Morris's section.]	6 0	6 0 to 7 0
3. "White Cale"—compact marly limestone (*Pecopteris polypodiodes*, in densely filled patches and with fronds in fructification, *Hinnites velatus*, *Lima*, sp., large *Pecten aratus*, *Pecten lens*, *Cypricardia nuculiformis*, *Unicardium impressum*, *Nerinæa cingenda*, &c.). [Bed 3 of Morris, 1 of my former section.]	1 0 to 1 6	1 6 to 2 0
4. Sandy soft bed. [4 of Morris, 2 of my former section.]	0 9	1 0
5. "Ringstone"—large oolitic grains in a very hard crystalline matrix (*Modiola Binfieldi*?). [5 of Morris, 3 of my former section.]	0 6	0 8
6. "Top Sand"—the peculiar laminated bed of my former section. The layers are somewhat inclined in Perkins's pit, but more so in Hill's pit, and very distorted in others. [6 of Morris?, 4 of my former section.]	2 0	2 0 to 2 6
7. "Brood"—a hard oolitic limestone, in courses of about 6 inches thickness, a good building-stone (*Natica Leckhamptonensis*, large new *Lima* *). [Wanting in Morris's section.]	3 0	1 6
8. "The Hard Sand"—a variable bed, sometimes much thicker (large *Natica Leckhamptonensis*, *Cardium Buckmani*, *Ostrea*). [6 of Morris? This and the last beds are wanting in my former section.]	0 9	1 0

* Allied to *L. grandis*, Römer?

	ft. in.	ft. in.	ft. in.	ft. in.
9. "The Hard Limestone"—in three or four courses, glistening in the fracture from the presence of small crystals of carbonate of lime, frequently blue-hearted, and a "first-rate building-stone" (*Avicula Münsteri, Gervillia acuta, Hinnites velatus, Lima*, sp., *Pecten aratus, P.*, small sp., *Pteroperna pygmæa, Cardium Buckmani, Ceromya concentrica, Lucina Wrightii, Natica Leckhamptonensis, Nerinæa*, sp., crustacean, *Pseudophyllia*, sp., *Ferns, Pecopteris polypodioides*, wood, &c. A zone filled with *Annelides* traverses this bed	2 0 to 3 0			2 0
10. "Bitch"—a soft marly material, good for lime-burning, but not for building-stone (*Pecten aratus*). [This and the last beds represent 5 of my former section.]		0 9	0 6	0 9
11. "Slates." [These beds, 9, 10, 11, would seem all to be included in slate-bed 7 of Morris.]	2 0 to 2 6		1 6 to 2 6	
12. "Sand"—Lower Estuarine with plants.				

In all the sections, some of the beds are divided by thin argillaceous seams.

Fossils from the Beds above the Slates, Collyweston.

Avicula Münsteri, *Goldf.*
Gervillia acuta, *Sow.*
Hinnites velatus, *Goldf.* sp.
Lima, large new sp. (allied to L. grandis, *Römer*)?
——, sp.?
Ostrea, sp.?
Pecten aratus, *Waagen.*
—— lens, *Sow.*
Pteroperna pygmæa, *Dunker*, sp.

Cardium Buckmani, *Mor. & Lyc.*
Ceromya concentrica, *Sow.*
Cypricardia nuculiformis, *Römer*, sp.
Lucina Wrightii, *Oppel.*
Modiola Binfieldi (?), *Mor. & Lyc.*
Unicardium impressum, *Mor. & Lyc.*

Natica Leckhamptonensis, *Lycett.*
Nerinæa cingenda, *Bronn.*
——, sp.?

Dentalium (?), new species.

Serpula, sp.?

Crustacean—
Pseudophyllia, sp.?

Ferns—
Pecopteris polypodioides, *Lindley.*
Wood.

Connected with the organic contents of the upper beds, the abundance of *Pecopteris polypodioides*, sometimes showing the delicate fructification beautifully preserved, is significant, as it seems to imply that the land surface upon which the *Pecopteris* grew could not have been very distant. The presence of the characteristic Inferior Oolite fossil *Natica Leckhamptonensis* throughout the section, the large new *Lima* with the shell beautifully preserved, and the small new *Dentalium* (?), are also worthy of particular notice.

Among the numerous fossils of the Slate beds, the little rare shell *Alaria Phillipsii* (first found, I believe, in the "Grey Limestone," Inferior Oolite, of Scarborough) claims attention; but the beautiful gasteropod *Pterocera Bentleyi* (named after my friend and former fellow worker, Mr. Bentley, of Stamford) seems chiefly to characterize these beds at Collyweston. The latter is by no means rare,

although the known examples have mostly been found in one quarry (Mr. Hill's); I think, however, that this is chiefly attributable to the fact that the intelligent quarryman, Mr. Lomax, preserves and dispenses to geologists all the fossils which he obtains. I have one good specimen of this peculiarly local fossil, found in the Lincolnshire Limestone at Denton, near Grantham (to which I shall presently allude); it occurs also in the shelly beds at Ponton, and I have already mentioned one other obtained by Mr. Judd from Morcot: but I believe it has not been detected in any other locality. On some of the slates, peculiar large worm-tracks are found.

Fossils from the Slate-beds, Collyweston.

Avicula Braamburiensis (?), *Sow.*
—— clathrata, *Lycett.*
—— Münsteri, *Goldf.*
—— subcostata, *Römer.*
——, sp.?
Gervillia acuta, *Sow.*
—— radians (?), *Mor. & Lyc.* (young).
Hinnites abjectus, *Phil.* sp.
—— tegulatus, *Mor. & Lyc.*
—— velatus, *Goldf.* sp.
Lima cardiiformis, *Sow.* sp.
—— gibbosa, *Sow.* sp.
——, sp.?
Pecten clathratus, *Römer.*
—— lens, *Sow.*
—— personatus, *Goldf.*
Pinna cancellata, *Bean.*
—— cuneata, *Phil.*
Placunopsis socialis, *Mor. & Lyc.*
Pteroperna costatula, *Deslongch.*
—— pygmæa, *Dunker*, sp.

Astarte elegans, *Sow.*
—— excavata, *Sow.*
—— depressa (?), *Goldf.*
—— compressiuscula (?), *Mor. & Lyc.*
Cardium Buckmani, *Mor. & Lyc.*
—— Stricklandi, *Mor. & Lyc.*
—— subtrigonum, *Mor. & Lyc.*
Ceromya concentrica, *Sow.*
——, sp.?
Cucullæa cancellata, *Phil.*
—— Goldfussii, *Römer.*
——, sp.?
Goniomya literata, *Sow.* sp.
Homomya (Myacites) unioniformis, *Mor. & Lyc.*
——, sp.?
Lucina Wrightii, *Oppel.*
——, sp?
Modiola gibbosa, *Sow.*
—— Sowerbyana, *d'Orb.*
Myacites decurtata, *Phil.* sp.
Trigonia costata, var. pullus, *Sow.*
—— compta, *Lycett.*
—— spinulosa (?), *Young & Bird.*
——, sp.?
Unicardium impressum, *Mor. & Lyc.*
——, sp.?

Alaria Phillipsii, *d'Orb.*, sp.
Cylindrites, new species, like turriculatus of *Lycett* (found at Ponton), but having fewer whorls.
Delphinula, sp.? (see Phil. Geol. Yorks. i. tab. ix. f. 32).
Natica (Euspira) canaliculata, *Lycett.*
——, sp.?
Pterocera Bentleyi, *Mor. & Lyc.*

Astropecten Cotteswoldiæ, var. Stamfordensis, *Wright* (from Slate-bed, St. Martin's, Stamford).

Fish—small teeth and scales.

Plants—small fragments.

The Collyweston Slate is now very much in request for roofing either restored or new buildings in Mediæval styles. It assorts well with such buildings; and, while fresh, is very eyeable. When the material and the workmanship are both of the best, it is tolerably durable; but if the slates are not picked, and if the workmanship is not better than ordinary, the roofs soon become dilapidated, ugly inequalities appear, the wind and the rain penetrate, and a slate roof then is neither sightly, efficient, nor lasting.

Sir Gilbert Scott has used this slate in his exquisite restoration of the beautiful Round Church at Northampton, and also for the roof

of the new Chapel of St. John's College, Cambridge; from the chippings at which place, through the kindness of Mr. Keeping of the Woodwardian Museum, I obtained a fine specimen of the *Pterocera Bentleyi.*

Easton.

The Ferruginous beds of the Northampton Sand, underlying the Lower Estuarine, thicken in Easton parish, and may be seen in some trial-holes, north of the village, on the hillside looking towards Tinwell. They are here some 15 feet in thickness, and consist of cellular ironstone of a rich character.

Wothorpe to St. Martin's.

Just east of Easton, reached by a slight descent, is Wothorpe Grove. Here, to the right, on the excavated side of the road, and high up on the southern escarpment of the Welland valley, may also be seen the Ferruginous beds of the Northampton Sand, overlying the Upper Lias Clay. The Lias on this side attains to a much higher elevation than on the Rutland side of the valley, and extends, in a kind of ridge, still capped with the ironstone, for a mile and a half to the north-east, into Burghley Park; at which point, it considerably overtops the town of Stamford. A copious spring, the drainage of the Lincolnshire Limestone and Northampton Sand to the south, occurs near to the Wothorpe ruins, at the junction of the latter bed with the Lias Clay; and the water is caught in reservoirs, which are of sufficient elevation to supply by gravitation every part of the town of Stamford.

Faults.

This discrepancy of level is the result of faults; one of which I have mentioned as traversing the section of the Geeston cutting near Ketton. Another strikes athwart the Welland valley and the Stamford parish of St. Martin, and extends some miles to the east. To the latter fault, and to its very remarkable and apparently anomalous consequences, I shall again allude*.

I would explain here, that, in the route I have taken for the purpose of description, many discrepancies of level, the effects of dip, of the bending of strata, and of faults, might have been noticed; but as these are not necessarily pertinent to my object, and have been mapped, and will be described, by Mr. Judd, I have deemed it not desirable to add to the length of my Memoir by particularly referring to them.

Area of Stamford Field and Neighbourhood.

Crossing the Welland valley, to the north of the town of Stamford, and into a nook of Lincolnshire, we come to the high ground well known as the Stamford Open Field, now in the process of being enclosed.

The highest point of Stamford Field is nearly 200 feet above the level of the river Welland. In this one hill-mass, we have the

* See Diagram of Section, Plate X. fig. 1.

hardly to be over-estimated advantage of a complete sequence of beds, ranging downwards from the Cornbrash to the Upper Lias inclusive. Here the beds tell their own tale, leaving little for surmise or for question as to their identity or order *.

Recent operations in connexion with enclosure led to the opening, at the highest point, of a shallow pit; thus exposing a section of Cornbrash, having a thickness of about four feet, seldom greatly exceeded in the district. From the stone of this pit, I obtained some usual Cornbrash fossils:—large *Ostrea Marshii*, Sow., *Terebratula sub-lagenalis*, Dav., *Dentalium entaloides*, Deslong., *Echinobrissus orbicularis*, Phil., &c. &c.

The Great Oolite Clay underlies the Cornbrash, although not exposed in any section. Below this, are beds of the Great Oolite Limestone; from which I have obtained:—

Avicula echinata, *Sow.*
Ceromya concentrica, *Sow.*
Modiola imbricata, *Sow.*
Ostrea Sowerbyi, *Mor. & Lyc.*
—— sub-rugulosa, *Mor. & Lyc.*
Rhynchonella concinna, *Sow.*
Ammonites, sp.?
—— gracilis, *Buckm.* (large),
Nautilus Baberi (?), *Mor. & Lyc.* (large septum).
Clypeus Mülleri, *Wright.*

Lower beds of this Limestone are seen at the top of the section in Torkington's brick-pit, overlying the extremely various and variegated beds of the Upper Estuarine Series; which consist here of—a reddish sandy bed, coarse shelly clay with plants, pale grey clay streaked with exceedingly shelly seams (sometimes containing *Cyrena* and similar freshwater or estuarine shells, and sometimes *Neæra Ibbetsoni, Pholadomya acuticosta, Modiola imbricata*, &c.), dark blue clay (shells with their tests preserved), and dark chocolate laminated clays.

These Estuarine beds have an aggregate thickness of about 27 feet, and are based by the ferruginous band; here strongly pronounced, and peculiar in its rather open structure, and in the presence of much wood.

Section in Torkington's Brick-pit, Stamford Field.

	ft. in.	ft. in.
1. Great Oolite Limestone—		
a. Limestone	1 0	
b. Sandy stone	1 0	
c. Grey clay	1 0	
d. Very soft marly white stone (*Rhynchonella concinna, Modiola imbricata, Ceromya concentrica*)	0 9	3 9
2. Upper Estuarine Series—		
a. Reddish sandy bed, in layers, sometimes passing into a "caley" stone	4 0	
b. Coarse shaly clay, with plants	3 0	
c. Grey clay, in layers full of shells (*Cyrena, Neæra Ibbetsoni, Pholadomya acuticosta, Modiola imbricata, Ostrea*, &c.), and containing plants and wood	2 0	

* See Diagram of Section, Plate X. fig. 1.

	ft. in.	ft. in.
d. Dark blue clay, with shells, the tests occasionally preserved	8 0	
e. Zone of chocolate-coloured indurated clay, thinly laminated	1 0	
f. Softer bed of chocolate-coloured clay—"the best for bricks"	4 0	
g. Yellowish clay	5 0	
h. Ferruginous band	0 9	27 9

At the base of this section, is the Lincolnshire Limestone—an oolitic freestone, similar to, and in the same position as, the upper beds of freestone in the Ketton quarries.

Fossils from the Upper Estuarine Beds, Stamford Field.

Cyrena, sp.?	Ostrea Sowerbyi, *Mor. & Lyc.*
Modiola imbricata, *Sow.*	Pholadomya acuticosta, *Sow.*
—— Lonsdalei, *Mor. & Lyc.*	Tancredia angulata, *Lycett.*
Neæra Ibbetsoni, *Morris.*	Plants and wood.

The beds of the Great Oolite Clay and Great Oolite Limestone crop out upon the escarpment of a very considerable circuit about this high ground; and the presence of the Upper Estuarine clays below is indicated by the occurrence of several brick-pits (in work or abandoned), and by a considerable stretch westward of an argillaceous moorland called the "Stamford Lings"—all upon the same level.

The freestone which appears at the base of the section in Torkington's brick-pit, is traceable westward, along the face of the escarpment, to the public Cemetery (where it has a thickness of some 10 or 12 feet), and on to the foot of the "Lings," where it was formerly quarried.

The northern boundary of the "Lings" is part of the southern boundary of Rutland; and north of this, just over and below the ridge, are the well-known Simpson's Little Casterton freestone quarries; the beds of which are geologically the same as those at Ketton, and the stone only second in quality and reputation to that of the older site: the fossils also nearly correspond. The freestone beds are surmounted by about 15 feet of the Upper Estuarine clays, which correspond exactly, in character and fossil contents, with the same series in Torkington's brick-pit.

Section at Simpson's Freestone Quarries.

	ft. in.	ft. in.
1. Upper Estuarine—Clay in various bands, and shelly zones, containing *Neæra Ibbetsoni*, *Modiola imbricata*, *Pholadomya acuticosta*, crystals of selenite, &c.		15 0
2. Lincolnshire Limestone—		

	ft. in. ft. in.
a. "Crash"—a soft freestone, crumbling upon exposure to frost and atmospheric action, and useless as building-stone, in two courses	4 0 to 5 0
b. "Rag"—an occasional pisolitic and shelly band, like the "Rag" at Weldon and Ketton	*nil* to 0 9
c. "Top Course"—good freestone	4 0

	ft. in. ft. in.	ft. in. ft. in.
d. "Bottom Course"—good freestone, but rather coarser in grain	2 0 to 2 6	
e. Hard band of crystalline limestone, full of comminuted shells	0 6	
f. Marly beds, not worked.	————	10 6 to 12 9

Fossils from Freestone Bed, Simpson's Quarries.

Avicula, smooth species.
Lima proboscidea, *Sow.* sp.
Ostrea gregaria, *Sow.*
—— sulcifera, *Phil.*
Lucina Wrightii, *Oppel.*
Homomya (Myacites) crassiuscula, *Mor. & Lyc.*
Trigonia costata, var. pullus, *Sow.*
Unicardium depressum, *Phil.*
Terebratula globata, *Sow.*
—— perovalis, *Sow.*
Chemnitzia vetusta (?), *Mor. & Lyc.*
Natica Leckhamptonensis, *Lycett.*
Nerinæa cingenda, *Bronn.*
—— Cotteswoldiæ, *Lycett.*
——, sp.? (like funiculus, *Deslong.*).
Trochus spiratus (?), *d'Arch.*
Pseudodiadema depressum, *Ag.*

At a little less than a mile north of Simpson's quarries, after, by a gradual descent, successively passing over the outcrop of the lower beds of the Lincolnshire Limestone, the Slate beds, and the Lower Estuarine and the Ferruginous beds of the Northampton Sand, (beds of the Great Oolite Limestone and the Upper Estuarine constituting the high tract to the east,) we come, at Casterton Parva, to the valley of the small Rutland river, the Gwash (*Gausenna* of the Romans); which flows over the Ferruginous beds of the Northampton Sand.

Nearly thirty years ago, a well of no great depth was sunk at this village, and a green and very fossiliferous phase of these beds was reached. From this bed Mr. Bentley and I obtained specimens containing numerous shells in excellent condition. The mineral character of these beds is very much like that of beds in the same position at the Duston ironstone quarries near Northampton, and is probably attributable (as I explained in my First Part) to the fact that the thickness of the overlying beds has prevented atmospheric oxidation. The fossils as a group correspond with those obtained from the upper portion of the Ironstone beds at Duston.

Fossils from Green Beds of Northampton Sand, from Well at Casterton Parva, Stamford, 1844.

Avicula inæquivalvis, *Sow.*
—— sp.? (young).
Gervillia, new sp.
Hinnites abjectus, *Phil.* sp.
Lima bellula, *Mor. & Lyc.*
—— duplicata, *Sow.* sp.
—— Dustonensis, *Etheridge*, M.S.
—— pectinoides, *Sow.* sp.
—— Pontonis, *Lycett.*
—— proboscidea, *Sow.* sp.
—— punctata, *Sow.* sp.
—— Rodburgensis, *Lycett*, M.S.
——, large sp. (allied to L. grandis, *Römer*)?
——, large sp.?
Lima, sp.
Ostrea flabelloides, *Lam.*
—— sulcifera, *Phil.*
Pecten arcuatus, *Sow.*
—— articulatus, *Schloth.*
—— demissus, *Phil.*
—— lens, *Sow.*
Perna rugosa, *Goldf.*
Plicatula tuberculosa, *Mor. & Lyc.*

———

Astarte elegans, *Sow.*
Cardium (near to) Stricklandi, *Mor. & Lyc.*
Ceromya concentrica, *Sow.*
Cucullæa cancellata, *Phil.*

Cucullæa, new sp.?
Lucina, new sp.?
Modiola imbricata, *Sow.*
—— Lonsdalei, *Mor. & Lyc.*
—— subreniformis, *Mor. & Lyc.*
—— sp.?
Opis lunulatus, *Sow.* sp. (a variety).
Unicardium, sp.?

Rhynchonella sub-decorata, *Dav.*
Terebratula ovoides, *Sow.*
—— perovalis, *Sow.*
—— sub-maxillata, *Sow.*

Actæon Sedgvici, *Phil.* sp.
Alaria trifida, *Phil.*
Natica, sp.? (small).
Nerinæa cingenda, *Bronn.*
—— triplicata, *Bronn.*
Trochus, sp.? (young).

Ammonites Murchisonæ, *Sow.*
—— ——, var. corrugatus, *Sow.*
Nautilus clausus, *d'Orb.*
Belemnites Bessinus, *d'Orb.*

Serpula, sp.?

Cidaris Wrightii, *Desor.*

Returning towards Stamford—below the freestone bed of the "Lings," is a very close and brittle marly limestone, in which *Rhynchonella Crossii*, Walker, occurs. Below this, are the series of marly and crystalline beds of the Lincolnshire Limestone exposed in Tinkler's and Squires's quarries, having a thickness of about 29 feet; some of them very fossiliferous, and containing zones of coral. A particular bed (containing much coral, many *Nerinææ*, and other fossils), very crystalline, and taking a high polish, was formerly called the "Stamford Marble," and was much used for chimney-pieces. The bed is still present in the section, but its mineral conditions are so altered as to unfit it for its former uses. In Squires's quarry (which nearly adjoins Tinkler's), a soft marly bed is thickly developed, and yields a very fine cream-coloured stone, easily worked, and (under the name of the "Stamford Stone") much used for chimney-pieces and for the interior carved work of churches. It contains many fossils, often in fine condition; many examples of a large *Natica* and of a very large *Lima*, and a beautifully preserved frond of a cycadaceous plant, have been obtained.

Fossils from the Marly Bed of Squires's Quarry.

Hinnites abjectus, *Phil.* sp.
Lima cardiiformis, *Sow.*
—— Etheridgii, *Wright.*
—— impressa, *Mor. & Lyc.*
—— proboscidea, *Sow.*
—— Pontonis, *Lycett.*
—— Rodburgensis, *Lycett*, M.S.
——, large sp. (allied to L. grandis, *Römer*)?
——, large sp.?
Pecten aratus, *Waagen.*
—— arcuatus, *Sow.*
—— clathratus, *Römer.*

Arca, large sp.?
Astarte elegans, *Sow.*
—— recondita, *Phil.*
Cardium Buckmani, *Mor. & Lyc.*
—— subtrigonum, *Mor. & Lyc.*
Ceromya Bajociana, *d'Orb.*
Ceromya similis, *Lycett.*
Cucullæa elongata, *Sow.*
Cypricardia Bathonica, *d'Orb.*
Cyprina Jurensis, *Goldf.*, sp.
—— Loweana, *Mor. & Lyc.*
Lucina Bellona, *d'Orb.*
—— despecta, *Phil.*
—— Wrightii, *Oppel.*
Macrodon Hirsonensis, *d'Orb.* sp.
Modiola Sowerbyana, *d'Orb.*
Myacites securiformis, *Phil.* sp.
Mytilus furcatus, *Goldf.*
Pholadomya Dewalquea, *Lycett.*
—— Heraulti, *Ag.*
Pholadomya lyrata, *Sow.*
—— ovalis, *Sow.*
—— ovulum, *Ag.*
——, sp.?
Tancredia axiniformis, *Phil.*

Rhynchonella sub-tetraëdra, *Dav.*
Terebratula perovalis, *Sow.*

Natica Leckhamptonensis, *Lycett.*
—— (like) Michelini, *d'Arch.*
——, sp. ?
Nerinæa cingenda, *Bronn.*
—— Cotteswoldiæ, *Lycett.*
—— Jonesii, *Lycett.*
Trochotoma obtusa, *Mor. & Lyc.*
—— tabulata, *Mor. & Lyc.*
Turbo depauperatus, *Lycett.*

Belemnites acutus, *Miller.*

Clypeus Michelini, *Wright.*
Stomechinus germinans, *Phil.*, large var.

Calamophyllia radiata, *Lamx.*
Latimæandra Flemingi, *Edw. & Haime.*
Thecosmilia gregaria, *M'Coy.*

Hybodus (dorsal spine).
Strophodus magnus, *Ag.* (palates).
—— subreticulatus, *Ag.* (palates).

Frond of cycadaceous plant.
Ferns—
Pecopteris polypodioides, *Lindley.*
Wood.

Section in Lincolnshire Limestone, Tinkler's Quarry, Stamford.

	ft. in.		ft. in.
1. Rubbly and broken limestone			4 0
2. Soft concretionary marly limestone, containing *Coral* zones, with *Perna*, *Lithodomus inclusus*, &c.			3 6
3. Marly limestone in thin layers, shivered			4 0
4. Compact marly limestone, in thin and irregular layers [I counted seven]			3 6
5. Very hard limestone, containing oolitic grains, sparsely distributed, occasionally very blue-hearted	2 0	to	2 6
6. Earthy shale bed, in very thin *laminæ*, containing numerous *Pectens* and other shells, with tests beautifully preserved, but crushed by compression	1 6	to	2 0
7. "Stamford Marble"—a very hard limestone, blue-hearted, and containing much *Coral*, *Nerinæa cingenda*, *N. triplicata*, numerous other shells, and teeth and palates of *Pycnodus Bucklandi* and *Strophodus magnus* and *S. subreticulatus*—formerly much more crystalline than in the present section, and then, when polished, a favourite material for chimney-pieces, &c., hence its name—in two courses	1 0	to	1 6
8. Very hard limestone, coarsely grained, in two courses	2 6	to	3 0
9. Compact marly stone, rather hard			1 6
10. Compact marly stone, softer, and containing *Nerinææ*—in three courses	3 0	to	3 6
11. Rather oolitic limestone, a good building-stone			1 0

Fossils from Freestone and Shelly Beds near to Tinkler's Quarry,

Arca pulchra, *Sow.*
Lima proboscidea, *Sow.* sp.
Pecten lens, *Sow.*
Pholadomya fidicula, *Sow.*
Serpula ?
Stomechinus germinans, *Phil.*
Strophodus magnus, *Ag.* (palates).

Fossils from Tinkler's and neighbouring Quarries.

Avicula clathrata, *Lycett.*
—— echinata, *Sow.*
Gervillia acuta, *Sow.*
Lima bellula, *Mor. & Lyc.*
—— Etheridgii, *Wright.*
—— Pontonis, *Lycett.*

Lima Rodburgensis, *Lycett*, M.S.
——, large sp. (allied to L. grandis, *Römer*)?
Ostrea flabelloides, *Lam.*
——, large flat species.
Pecten aratus, *Waagen.*
—— arcuatus, *Sow.*
—— clathratus, *Römer.*
—— demissus, *Phil.*
—— lens, *Sow.* (or large new sp.?).
—— personatus, *Goldf.*

Arca Prattii, *Mor. & Lyc.*
Astarte elegans, *Sow.*
—— minima, *Phil.*
Ceromya Bajociana, *d'Orb.*
—— similis, *Mor. & Lyc.*
Cyprina Jurensis, *Goldf.*
—— Loweana, *Mor. & Lyc.*
—— trapeziformis, *Römer.*
Cypricardia Bathonica, *d'Orb.*
—— nuculiformis, *Römer.*
Goniomya V-scripta, *Sow.*
Lithodomus inclusus, *Phil.*
Lucina Bellona, *d'Orb.*
—— Wrightii, *Oppel.*
Modiola Sowerbyana, *d'Orb.*
Myacites calceiformis, *Phil.* sp.
—— decurtata, *Phil.* sp.
—— securiformis, *Phil.* sp.
Pholadomya Dewalquea, *Lycett.*
—— fidicula, *Sow.*
—— Heraulti, *Ag.*
—— ovalis, *Sow.*
——, sp.?
——, sp.?
Tancredia axiniformis, *Phil.*
Trigonia costata, var. pullus, *Sow.*
—— sculpta, *Lycett.*
—— V-costata, *Lycett.*
——, sp. (new)?
Unicardium, sp.?

Rhynchonella crucis, *Walker.*
—— sub-decorata, *Dav.*
—— sub-tetraëdra, *Dav.*
Terebratula globata, *Sow.*
—— perovalis, *Sow.*
—— sphæroidalis, *Sow.*
—— sub-maxillata, *Sow.*

Actæonina, large species?
Natica (Euspira) canaliculata, *Mor. & Lyc.*
—— formosa, *Mor. & Lyc.*
—— grandis, *Goldf.*
—— Leckhamptonensis, *Lycett.*
Nerinæa gracilis, *Lycett.*
—— cingenda, *Bronn.*
—— Jonesii, *Lycett.*
—— Oppelii, *Lycett.*
—— triplicata, *Bronn.*
Phasianella elegans, *Mor. & Lyc.*
Pterocera, sp.? (like ignobilis, *Mor. & Lyc.*).

Ammonites Murchisonæ, *Sow.**
—— subradiatus, *Sow.*
—— terebratus, *Phil.*
—— (large septa, very like species found in Ferruginous beds at Duston).
Nautilus obesus, *Sow.*
—— polygonalis, *Sow.*
Belemnites Bessinus, *d'Orb.*

Serpula convoluta, *Goldf.*

Galeropygus (Hypoclypus) agariciformis, *Forbes.*
Holectypus hemisphæricus, *Ag.*
Pygaster semisulcatus, *Phil.*
Pentacrinus, sp.?

Anabacia orbulites, *Edw. & Haime.*
Cladophyllia Babeana, *Edw. & Haime.*
Isastræa limitata, *Edw. & Haime.*
Montlivaltia tenuilamellosa, *Edw. & Haime.*
Thamnastræa, sp.?
Thecosmilia gregaria, *M'Coy.*

Hybodus (large spine).
Pycnodus Bucklandi, *Ag.* (teeth).

Teleosaurus (tooth).

Pecopteris polypodioides, *Lindley.*
Coniferous wood.

Some years ago, in a rather wide crevice, formed by an open joint, in the upper beds of Tinkler's quarry, were found—canine and molar teeth of two individuals of *Hyæna* of different ages, portions of a very diminutive tooth of *Elephas*, large cervine molar (perhaps *Megaceros*?), small cervine molar, and some gnawed bones. These are in my possession, and have been kindly identified for me by Professor Rolleston, F.R.S. So far as I know, this is the only

* In the Museum of the Stamford Institution.

instance of the remains of carnivorous *mammalia*, or of any thing allied to a cave-deposit, which has occurred in this part of England.

By a well sunk at the distance of a few yards from Tinkler's quarry, limestone and other beds are shown to extend downwards for some 20 feet below the floor of the quarry, Slate appearing at the bottom. It is probable that some of these beds are analogous to the superincumbent beds of Collyweston.

Professor Morris, in his well-known Paper on the Lincolnshire Oolites, published in the Society's Journal for 1853, gives, on page 336, the following as a foot-note:—

"At Tinkler's quarry and the adjoining lands near Stamford, a typical series of the whole district may be observed. In a higher part of the hill, the stratified and bituminous clays, with the ferruginous band, may be observed, overlying the freestones (Ketton and Casterton): the lower parts of the freestones form the top of the quarry; below which—

		ft.	in.
1.	Compact oolitic rock, few shells	2	0
2.	Concretionary compact marly oolite, full of shells, and zones of corals, the bottom more compact, the upper part marly, and decomposes more rapidly, containing shells in great abundance	4	0
3.	Compact hard shelly oolitic rock, *Nerinæa*, &c.	2	6
4.	Compact oolitic rock, somewhat crystalline	1	6
5.	Shaly bed, irregular laminated fragments of plants, and many compressed shells, *Lucina*, *Pecten*, &c.	2	0
6.	"Stamford Marble"—very compact marly limestone, full of shells and corals, *Nerinæa* abundant	2	6
7.	Indurated, somewhat marly rock	3	0
8.	Compact rock	1	6
9.	Compact, marly, coarse-grained oolitic rock	2	6
10.	Fine-grained oolitic rock	1	0
11.	Cream-coloured marly rock*; with *Nerinæa* abundant, *Lima*, *Terebratula*, *Isocardia* (*Ceromya*), *Modiola*, *Lucina*, &c.	1	6
12.	Coarse oolitic rock 2 feet to	26	0

Probably resting on the sands with slaty beds, which have been found in sinking lower down the hill, overlying the ferruginous rock, which covers the Upper Lias."

This series, thus noted by Professor Morris twenty years ago, may still be considered, so far as it goes, to be "typical" of the district; but, as might be expected, the then section in Tinkler's quarry does not exactly agree with that now exposed; which, of course, is at some distance from the former site. A comparison will exhibit differences, and yet a remarkable coincidence. Although entirely different sets of figures represent the various thicknesses of the beds of the two sections, these figures, when summed up, give total thicknesses for the two sections almost identical. Thus, the section recently measured by me exposes a thickness of about 29 feet, to which may be added the further thickness of 20 feet penetrated by the well, giving a total thickness of 49 feet. Professor Morris's measured and estimated thicknesses amount together to 50 feet; the difference being only one foot.

The coincidence seems to me very significant. However variable

* This represents the marly bed, the "Stamford Stone," of Squires's quarry.

and discrepant the rate of deposition at the two points during the passage of time represented by the whole thickness of beds, the aggregate amount of deposit at both points only differed in the proportions of 49 to 50.

The measurements of the beds of the Lincolnshire Limestone exposed at Simpson's Quarry, on the "Lings," in Tinkler's Quarry, and in the well, give 65 feet as the total thickness of the formation here.

A well at Torkington's brick-pit (half a mile to the east) pierces through a thickness of 74 feet of the same beds; this about tallies with the thickness pierced by a well sunk by Mr. Browning the architect, at a somewhat lower level in North-street, allowing for a diminution of thickness at the top.

Some excavations were recently made, at a lower level than Tinkler's Quarry, near to the Scotgate entrance to Stamford; which exhibited the Slate beds reposing on the Lower Estuarine Sands.

For the foundations and cellars of the houses of the Rock Terrace, hard by, excavations were made in the Ferruginous beds of the Northampton Sand; so that the surface of the Upper Lias Clay cannot be many feet below the level of the street at this point.

Thus it has been shown that the escarpment of the high ground north of Stamford presents a complete sequence of beds, from the Cornbrash at the summit to the Upper Lias at the base; the Lincolnshire Limestone being by far the most important formation of the whole group *.

The District East and North-East of Stamford.

To the east and north-east of Stamford, the various beds are considerably depressed. On the road to Uffington, immediately north of the bridge which passes over the Stamford and Essendine Railway, and abutting upon the deep cutting here, is Mr. Eldret's quarry; in which is a fine section, exposing a thickness exceeding 30 feet of beds of the Lincolnshire Limestone.

The floor of this quarry is only a few feet higher than the level of the Welland river at this point, although the base of the limestone has not been reached.

This is a very good typical section of the middle beds of the formation; which here has thickened considerably. It consists of a series of fifteen distinct beds of limestone, of varying character: some are oolitic (one being a true "freestone"), and these are in an unusual position, at the bottom of the section, while others, and by far the greater part, are marly, and devoid of oolitic grains; some are soft, like the Squires's-pit "Stamford Stone," while others are hard, and sometimes crystalline and blue-hearted; some are very fossiliferous, while others are slightly so, and some apparently bare of fossils. In my detailed notes of this section, I have recorded the peculiar names by which the several beds are identified by the quarrymen.

* See Diagrammatic Section, Plate X. fig. 2.

Section at Eldret's Quarry, with Quarrymen's Terms.

	ft.	in.
1. "Rammel"—broken stone, about	4	0
2. "Clinkers"—compact marly whitish stone, very good for lime-burning: has a glistening fracture	2	0
3. "Pendle"—hard, flaggy limestone, rather oolitic, deeper in colour than the last, in thin layers	2	0
4. "Shelly Course"—composed wholly of shells with corals, very hard, ("Stamford Marble"?)	2	6
5. "Bullymong"—soft white marly limestone, containing numerous fossils, (like the "Stamford Stone" of Squires's quarry), more compact and harder towards the bottom...	4	0
6. "Blue Limestone"—hard compact stone, blue-hearted, good rubble walling-stone	4	6
7. Course of cream-coloured clay	0	2
8. Hard limestone, with oolitic grains	1	0
9. "Bastard Freestone"—an oolitic limestone, in two courses	3	0
10. Hard and compact marly course	0	7
11. Soft white marly limestone (like the "Stamford Stone" of Squires's quarry), in four courses of different thickness ...	5	0
12. "Caley" oolitic bed (like some of the upper beds at Collyweston)	1	0
13. "Bastard Freestone," containing concretionary masses of very hard limestone	1	6
14. "Freestone"—a good oolitic freestone	1	1
15. Limestone—thickness not ascertained.		

Belmisthorpe.

Two miles north of Eldret's Quarry, the railway, after crossing the valley of the Gwash, passes, by a cutting, through the Great Oolite Limestone and the underlying Upper Estuarine Clays. This cutting is distant only two miles to the north-east from the summit of the Stamford Field, and yet the beds here exposed are nearly 100 feet lower in level than the same beds in their elevated position at the last-named site. From these beds at Belmisthorpe, I have an abundance of Great Oolite fossils of forms rendered familiar by their frequent occurrence in the Great Oolite beds of the Northampton district.

Fossils from Great Oolite Limestone at Belmisthorpe.

Lima cardiiformis, *Sow.* sp.
Ostrea sub-rugulosa, *Mor. & Lyc.*
Pecten annulatus, *Sow.*
Pinna cuneata, *Phil.*

———

Cardium Buckmani, *Mor. & Lyc.*
—— subtrigonum, *Mor. & Lyc.*
Ceromya Symondsii, *Mor. & Lyc.*
——, sp. ?
Corbis Bathonica, *Mor. & Lyc.*
Cucullæa, sp. ?
Cypricardia Bathonica, *Mor. & Lyc.*
Cyprina depressiuscula, *Mor. & Lyc.*
Gresslya peregrina, *Phil.*
Homomya Vezelayi, *d'Arch.* sp.
Homomya crassiuscula, *Mor. & Lyc.*
Isocardia tenera, *Sow.*
Macrodon Hirsonensis, *d'Arch.* sp.
Modiola imbricata, *Sow.*
Myacites calceiformis, *Phil.* sp.
—— securiformis, *Phil.* sp.
—— Terquemea, *Buv.* sp.
Neæra Ibbetsoni, *Morris.*
Pholadomya deltoidea, *Sow.*
—— lyrata, *Sow.*
—— oblita, *Mor. & Lyc.*
—— socialis, *Mor. & Lyc.*
—— solitaria, *Mor. & Lyc.*
——, new round sp.? with irregular *costæ**.

* Found also at Danes' Hill, near Peterboro', and near Northampton—all in the Great Oolite Limestone.

Trigonia costata, var. pullus, *Sow.*
—— ——, var. elongata, *Sow.*
—— Moretoni, *Mor. & Lyc.*
Unicardium varicosum, *Sow.*

Natica formosa, *Mor. & Lyc.*
—— grandis, *Goldf.*
—— intermedia, *Mor. & Lyc.*

Nautilus Baberi, *Mor. & Lyc.* (very numerous and large).
—— subtruncatus, *Mor. & Lyc.*

Crustacean—
Eryma (allied to) elegans, *Oppel.*

Fossils from the Upper Estuarine Clays, Belmisthorpe.

Terebratula intermedia, *Sow.*
Crustacean—
Eryma (allied to) elegans, *Oppel.*
Hybodus, large dorsal spine.
Teleosaurus, large vertebræ and bones.
——, large and numerous scutes.
——, small jaw.
——, small atlas.

Fossils from Great Oolite, Uffington, adjoining Belmisthorpe.

Lima duplicata, *Sow.* sp.
Isocardia tenera, *Sow.*
Pholadomya deltoidea, *Sow.*
Pholadomya Heraulti, *Ag.*
Ammonites macrocephalus, *Schloth.* (a large example).

Great Northern Railway.

Half a mile beyond the Belmisthorpe cutting, the Stamford and Essendine Railway joins the main line of the Great Northern Company. The sections exposed in the cuttings of this line between Peterboro' and Grantham have been rendered classical by their description by Professor Morris in a Paper published nearly twenty years ago in the Quarterly Journal of this Society*; and which Paper constitutes the only existing reliable record of these valuable sections, long since covered up.

In this long interval, some advance has been made in the knowledge of the geology of this part of England; and, as additional light has been thrown upon the character and sequential position of the beds then described, I shall perhaps be justified in redirecting attention to these sections, and, while adopting Professor Morris's descriptions, in venturing to assign some of the beds to other formations than those to which he referred them. It must not be forgotten, however, that in his interesting article in the 'Geological Magazine' for March, 1869, Professor Morris indicated that the views which he had formerly entertained had undergone much modification†.

By taking these sections in succession in a direction from south to north, a very complete sequence of the beds (from the Oxford Clay to the Lincolnshire Limestone inclusive) of this Midland part of the country will be obtained; and I shall endeavour to apply them as one group of evidence as to what that sequence really is,

* Nov. 1853.

† As far back as the date of Professor Morris's Paper in 1853, Dr. Lycett had arrived at the provisional conclusion that the beds now known as the Lincolnshire Limestone were Inferior Oolite; and even three years previously, the Rev. P. B. Brodie, F.G.S., in a paper published in the 'Proceedings of the Cotteswold Field Club,' expressed an opinion that some beds of the limestones of Lincolnshire should be classed rather with the Inferior than with the Great Oolite.

Fig. 2.—*Section at Casewick Cutting**.

Length 39 chains. Vertical scale 120 feet to 1 inch.

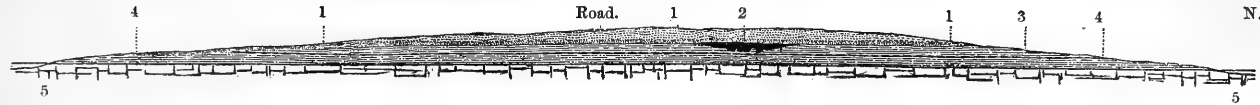
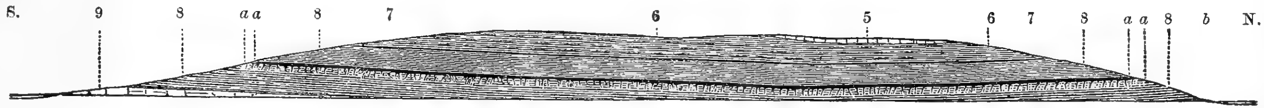


Fig. 3.—*Section at Danes'-Hill Cutting**

Length 22 chains. Vertical scale 120 feet to 1 inch.



1. Drift beds.
2. Intercalated freshwater bed.
3. Oxford Clay.
4. Kelloway rock.
5. Cornbrash.
6. Great Oolite Clay.
7. Great Oolite Limestone.
8. Great Oolite Upper Estuarine.
   aa. Plant bed.
   b. Ferruginous band.
9. Lincolnshire Limestone.

* Taken by the kind permission of Professor Morris, F.G.S., from his Paper "On the Lincolnshire Oolites," Quart. Journ. Geol. Soc., Nov. 1853.

and as to the true geological character of the beds of which it consists.

During the progress of the excavation of these cuttings, Mr. Bentley and I had the advantage of traversing them more than once in the instructive company of Professor Morris; and I am fortunate in possessing, and in being enabled to exhibit a selection from, fossils gathered on those occasions by Mr. Bentley and myself.

Casewick Cutting.

The most southerly of these cuttings is at Casewick, about three miles to the south-east of Stamford. The upper part of the section consists of 8 feet of Quaternary Drift beds; between which and the Secondary beds, is intercalated, for the space of about 30 yards, a freshwater deposit: these are of sufficient interest in themselves, but are foreign to my subject. Professor Morris describes the uppermost Secondary bed in this cutting as being Oxford Clay: he then gives Kelloway Rock, and then Oxford Clay again: the lowest bed of the section and the floor of the cutting consist of Cornbrash.

I have characteristic fossils from each of the beds of this section, including—*Ammonites Herveyi*, *A. biplex*, and *A. Gowerianus*, from the Oxford Clay; *Gryphæa bilobata*, in every stage of growth, and the very characteristic *Avicula expansa*, from the Kelloway Rock; and two fair specimens of the rare and peculiar *Terebratula Bentleyi* from the Cornbrash.

Fossils from the Casewick Cutting.

Oxford Clay.

Ammonites biplex, *Sow.*
Am. Gowerianus, *Sow.*
Am. Herveyi, *Sow.*

Kelloway Rock.

Avicula expansa, *Phil.*
Gryphæa bilobata, *Sow.*
—— dilatata, *Sow.*
Ostrea, sp.?
——, sp.?
Pecten, sp.?
Gresslya peregrina, *Mor. & Lyc.*
Modiola pulchra, *Phil.*
Myacites calceiformis, *Phil.* sp.
Myacites recurva, *Phil.* sp.
Myopsis dilatata, *Phil.* sp. (or new sp.?).
—— sp.?
Trigonia, sp.?
Serpula intestinalis, *Phil.*
Belemnites hastatus, *Blainv.*
Megalosaurus, sp.? (bone).

Cornbrash.

Lima pectiniformis, *Schloth.*
—— rigida, *Sow.* sp.
—— rigidula, *Sow.* sp.
Ostrea, large flat sp.
Goniomya V-scripta, *Sow.* sp. (large var.)
Pholadomya acuticosta, *Sow.*
Rhynchonella concinna, *Sow.* sp.
—— Morieri, *Dav.*
Terebratula Bentleyi, *Morris.*
Serpula intestinalis, *Phil.*
——, sp.?
Strophodus magnus, *Ag.* (palates).

Banthorpe Cutting.

At less than a mile north of Casewick, is the Banthorpe cutting.

The Cornbrash which based the last section appears at the top of this: beneath the Cornbrash, appears the Great Oolite Clay; and underlying it, to the depth of 7 feet, is the Great Oolite Limestone of Belmisthorpe and the Stamford Field. From the Clay, I obtained a fine caudal vertebra of *Cetiosaurus*, that largest of all known Saurians; and this Clay, be it noted, is in the exact relative position as that at Kirklington in Oxfordshire, whence Professor Phillips obtained the wonderful and unique skeleton with which he has enriched the Oxford Museum. From the Limestone, I collected a large example of *Nautilus Baberi*, which occurs so abundantly in the Great Oolite Limestone of Northampton, and which equally distinguishes the equivalent bed at Belmisthorpe. The Cornbrash at Banthorpe has yielded *Pecten vagans*, Sow., and *Myacites calceiformis*, Phil. sp.

Essendine, Aunby, and Danes' Hill.

A mile from Banthorpe, is the Essendine cutting, and at short intervals the Aunby and the Danes'-Hill cuttings. Professor Morris has given the details of these sections with considerable minuteness; but, as they are not widely separated, and present no differences that will affect my position, I will include them in one general description:—

The Cornbrash, which bases the Casewick cutting, and caps the Banthorpe section, occurs in patches upon the summit of the section at Danes' Hill, and thus serves to preserve the continuity of the sequence through this widely extended, interesting, and significant series of sections. (See *antè*, figs. 2 and 3.)

Below the Cornbrash, (and occurring at Danes' Hill only,) are compact marly and sandy beds, with shells, about 5 feet in thickness, which perhaps may be considered equivalent to Forest Marble.

These overlie the Great Oolite Clay, containing bands of *Ostrea sub-rugulosa* in a normal horizontal position, and occasional patches of *Serpulæ*. This clay, in the several sections, varies in thickness from 5 feet to 8 feet.

Next, in descending order, is the Great Oolite Limestone—8 feet to 12 feet—described by Professor Morris as a "sandy and marly rock, becoming occasionally very compact, calcareous, bluish, and sometimes shaly": at Danes' Hill, it is divided by argillaceous bands. From this bed, many Great Oolite fossils have been obtained.

The Upper Estuarine series consists here of numerous bands of very varying sands and clays; which are sometimes very shaly, sometimes bituminous, and occasionally assume the character of a soft marly rock. The fossils noted are of well-known Great-Oolite forms, interspersed with some of undescribed species. The presence of layers of *Cyrena*, other estuarine shells, much wood (almost converted into jet), and of other vegetable matter, characterizes this bed; which is traversed at Essendine and Danes' Hill by one band, and at Aunby by two bands, of peculiar plant-growth (precisely

like that described by me as occurring in the sand-bed at Kingsthorpe), consisting of vertical root-perforations surmounted by horizontal bituminous layers. This Upper Estuarine series was not wholly exposed at Essendine: at Danes' Hill, it had a thickness of about 22 feet; while at Aunby, it had thickened to no less than 32 feet. The usual ferruginous band, of the thickness of about a foot, based these clays.

At the southern end of the Danes'-Hill cutting, and immediately underlying the ferruginous band, an upper bed of the Lincolnshire Limestone was exposed.

In the Essendine cutting, and probably in the Great Oolite Clay (the same clay as that at Banthorpe and at Kirklington), immense bones of *Cetiosaurus brevis* and of *C. longus* were found; which bones are now in the Museum in Jermyn Street.

As no useful end can be served in keeping distinct the fossils of these sections, I have grouped them together in the following list, in order to economize space and to avoid repetition.

Fossils from the Essendine and Danes' Hill Cuttings.

CORNBRASH.

Terebratula ornithocephala, *Sow.*
Terebratula sub-lagenalis, *Dav.*

GREAT OOLITE LIMESTONE.

Gervillia Islipensis, *Lycett.*
Lima cardiiformis, *Sow.* sp.
—— duplicata, *Sow.* sp.
Ostrea Sowerbyi, *Mor. & Lyc.*
—— sub-rugulosa, *Mor. & Lyc.*
——, sp.?
Pecten annulatus, *Sow.*
—— lens (?), *Sow.* (or new sp.?).
——, sp.?
Perna foliacea, *Lycett.*
—— (like) mytiloides, *Lam.*
—— quadrata, *Sow.* sp.
—— rugosa, *Goldf.*
——, sp. new?
Pteroperna emarginata, *Mor. & Lyc.*
——, plana, *Mor. & Lyc.*
——, sp?

Arca Eudesii, *Mor. & Lyc.*
——, sp.?
Cardium Buckmani, *Mor. & Lyc.*
—— cognatum, *Phil.*
—— lingulatum, *Lycett.*
—— Stricklandi, *Mor. & Lyc.*
—— subtrigonum, *Mor. & Lyc.*
—— sp.?
Ceromya Symondsii, *Mor. & Lyc.*
Cypricardia caudata, *Lycett.*
Cypricardia nuculiformis, *Römer.*
Cyprina Davidsoni, *Lycett.*
—— Loweana, *Mor. & Lyc.*
——, sp.? (var. elongata?).
Isocardia tenera, *Sow.*
Modiola cuneata, *Sow.*
—— gibbosa, *Sow.*
—— imbricata, *Sow.*
—— Lonsdalei, *Mor. & Lyc.*
—— subreniformis, *Mor. & Lyc.*
Myacites calceiformis, *Phil.* sp.
—— securiformis, *Phil.* sp.
Neæra Ibbetsoni, *Morris.*
Opis, new sp.*
Pholadomya deltoidea, *Sow.*
—— Heraulti, *Ag.*
—— lyrata, *Sow.*
—— Phillipsii, *Morris.*
—— socialis, *Mor. & Lyc,*
——, new sp.? with a few coarse *costæ*†.
——, new round sp.?, with irregular *costæ*‡.
Tancredia axiniformis, *Phil.*
Trigonia costata, *Sow.*
—— Moretoni, *Mor. & Lyc.*
Unicardium varicosum, *Sow.*

Rhynchonella concinna, *Sow.* sp.

* Found also at Stowe-Nine-Churches, near Weedon.
† Found also near Peterboro' and at Kingsthorpe.
‡ Found also at Belmisthorpe, near Peterboro', and near Northampton, all in Great Oolite Limestone.

Terebratula intermedia, *Sow.*
—— maxillata, *Sow.*
—— obovata, *Sow.*

Amberleya nodosa, *Mor. & Lyc.*
Delphinula?
Natica formosa, *Mor. & Lyc.*
—— globosa, *Römer.*
—— intermedia, *Mor. & Lyc.*
—— (Euspira) canaliculata, *Mor. & Lyc.*
—— —— pyramidata, *Mor. & Lyc.*
—— —— Sharpei, *Mor. & Lyc.*
Trochotoma, sp.?

Nautilus Baberi, *Mor. & Lyc.*
—— subtruncatus, *Mor. & Lyc.*

Serpula, new sp.

Acrosalenia hemicidaroides, *Wright.*
—— pustulata, *Forbes.*
—— Wiltoni, *Wright.*
Clypeus Mülleri, *Wright.*

Crustacean—
Eryma (allied to) elegans, *Oppel.*

UPPER ESTUARINE CLAYS*.

Avicula, sp.?
Lima, sp.?
Ostrea Sowerbyi, *Mor. & Lyc.*
——, sp.?
Pecten retiferus (?), *Mor. & Lyc.*
——, sp.?
Pinna, new species?

Arca rugosa, *Mor. & Lyc.*
——, sp.?
Astarte angulata (?), *Mor. & Lyc.*
Cardita?
Cardium Stricklandi, *Mor. & Lyc.*
—— subtrigonum, *Mor. & Lyc.*
Cucullæa concinna, *Phil.* sp.
—— triangularis (?), *Phil.* sp.
——, sp.?
Cypricardia Bathonica, *d'Orb.*
—— caudata, *Lycett.*
——, sp.?
Cyprina Loweana, *Mor. & Lyc.*
——, var. elongata?
——, sp.?
Cyrena, sp.?
Gresslya, sp.?
Modiola imbricata, *Sow.*
—— gibbosa, *Sow.*
——, sp.?
Myacites, sp.?
Neæra Ibbetsoni, *Morris.*
Pholadomya acuticosta, *Sow.*
Tancredia axiniformis, *Phil.*
—— planata, *Mor. & Lyc.*
Tellina, sp.?
Thracia, sp.?
Unicardium gibbosum, *Mor. & Lyc.*
—— impressum, *Mor. & Lyc.*
—— varicosum?, *Mor. & Lyc.*

Rhynchonella concinna, *Sow.* sp.

Cerithium, sp.?
Natica, sp.?

Acrosalenia, sp.? (spines).

Plants—in both horizontal and vertical positions.
Wood—converted almost into jet.

Identity of Fossils of the Great Oolite of Stamford with those of the Great Oolite of Northampton.

As I shall not again refer in detail to the beds of the Great Oolite, I will here point to the identity of the organic forms which are most abundant or most significant in the beds of that formation in the Northampton district, with those of the greatest frequency or of equal significance in the beds which I have termed "Great Oolite" in the Stamford district; by which identity, as I think, the equivalency of these beds in the two localities is palæontologically established.

The most prominent fossil probably in the Great Oolite Limestone of Northampton is the large *Nautilus Baberi*; of which numerous examples have been found in the limestone of Belmisthorpe,

* The fossils in the Upper Estuarine Clays are for the most part very imperfectly preserved; and it must be understood, therefore, that the fossils in the list marked with a note of interrogation are only probably identified.

and others in similar beds at Banthorpe, Essendine, and near Peterboro'.

Large specimens of *Ammonites gracilis*, Buckm., occur in the Northampton beds; I have a less large example from Stamford.

Natica formosa, *N. intermedia*, and other species of *Natica* having elevated spines, occur in great numbers at Kingsthorpe and Blisworth; they are prevalent forms also at Belmisthorpe, Essendine, and Danes' Hill.

Pholadomya (*deltoidea*, *Heraulti*, *lyrata*, *socialis*, &c.) is a most abundant genus in the Northampton beds: it is as abundant and various at Belmisthorpe, and also occurs at Essendine and Danes' Hill.

Modiola imbricata is equally numerous in the beds of both districts, as are also *Myacites calceiformis*, *Cypricardia Loweana*, and *Isocardia tenera*.

Terebratula maxillata and *Rhynchonella concinna*, such marked forms at Blisworth and Kingsthorpe, distinguish also Danes' Hill and Essendine.

Other forms, of less abundance but of much significance, are common to the beds which I have termed "Great Oolite" in both localities; such as the rare *Amberleya nodosa* of Mor. & Lyc., the still more rare *Neæra Ibbetsoni* (known only, I believe, in the Great Oolite beds of these localities), and the beautiful undescribed crustacean allied to *Eryma elegans* of Oppel, so abundant at Buttock's Booth near Kingsthorpe, and also found at Belmisthorpe, Essendine, and Danes' Hill.

Besides these, are the abundant and puzzling series of shell-less fossils, so difficult of recognition; and which the great experience and persistent patience of Mr. Etheridge alone enabled him approximately to identify. Among these, are *Ceromya Symondsii*, *Cypricardia Bathonica*, *Cardium Buckmani*, *Unicardium*, and others; the similarity of which, both as to condition and form, in the groups obtained from the two localities, also serves to mark the parallelism of the beds whence they have been derived.

Little Bytham.

At Little Bytham, two miles north of Danes' Hill, the Great Oolite Limestone has disappeared; but the Upper Estuarine Clays exhibit a thickness of about 30 feet, and the ferruginous band at the base is still present, as it is in several other cuttings further north. Below the Clays, the Lincolnshire Limestone appears in the form of good oolitic freestone; and this (for the sake of the stone) was excavated, during the making of the railway, to a considerable depth below the floor of the cutting. Under 10 feet of this freestone, was found a compact marly limestone, 3 feet in thickness; and beneath this again, 8 feet of good freestone.

The Pontons.

Four miles south of Grantham, is the Great Ponton cutting. Under about 6 feet of the Upper Estuarine Clays, are 37 feet of the

beds of the Lincolnshire Limestone:—Beneath 5 feet of rubbly oolite, are a series of shelly, coralline, and oolitic bands (having an aggregate thickness of 15 feet), which have yielded a perfect harvest of fossils, including many forms not previously known; some of which were described and figured by Dr. Lycett in an Appendix to Professor Morris's Paper. Under these shelly bands, is a soft marly limestone, 3 feet; and below this, 15 feet of "coarse shelly oolites and freestones."

Nearer Grantham, is the Little-Ponton cutting; in which is exposed 50 feet of the beds of the Lincolnshire Limestone. A well in the neighbourhood pierced through some 60 feet of the same beds.

Fossils from the Shelly Beds, Ponton.

Gervillia acuta, *Sow.*
Hinnites velatus, *Goldf.* sp.
—— tegulatus, *Mor. & Lyc.*
Lima bellula, *Mor. & Lyc.*
—— cardiiformis, *Mor. & Lyc.*
—— duplicata, *Sow.* sp.
—— gibbosa, *Sow.* sp.
—— Pontonis, *Lycett.*
—— punctata, *Sow.* sp.
Ostrea flabelloides, *Lam.*
—— gregaria, *Sow.*
—— sulcifera, *Phil.*
Pecten lens, *Sow.*
——, sp.?
Plicatula tuberculosa, *Mor. & Lyc.*
——, sp.?
Pteroperna costatula, *Deslong.* sp. (young).
—— plana, *Mor. & Lyc.*
—— pygmæa, *Dunker,* sp.

Arca æmula, *Phil.*
—— Prattii, *Mor. & Lyc.*
—— pulchra, *Sow.*
Astarte depressa, *Goldf.*
—— elegans, *Sow.*
—— excentrica, *Mor. & Lyc.*
—— minima, *Phil.*
—— Pontonis, *Lycett.*
—— Wiltoni, *Mor. & Lyc.*
——, sp.?
Cardium, sp.?
Ceromya similis, *Lycett.*
Cypricardia Bathonica, *d'Orb.*
Cyprina nuciformis, *Lycett.*
——, sp.?
Cytherea (Cyprina) dolabra, *Phil.*
Homomya crassiuscula, *Mor. & Lyc.*
Lucina Bellona, *d'Orb.*
—— despecta, *Phil.*
—— ——, var. cardioides, *d'Arch.*
—— rotundata, *Römer.*
—— Wrightii, *Oppel.*
Macrodon Hirsonensis, *d'Arch.* sp.
Modiola Binfieldi, *Mor. & Lyc.*
Modiola gibbosa, *Sow.*
——, sp.?
Myoconcha crassa, *Sow.*
Opis gibbosus, *Lycett.*
—— lunulatus, *Sow.* sp.
—— similis, *Desh.* (or new sp.?).
——, smooth new sp.?
Tancredia angulata, *Lycett.*
—— axiniformis, *Phil.*
Trigonia costata, *Park.*
—— ——, var. pullus, *Mor. & Lyc.*
—— hemisphærica, *Lycett.*
Unicardium depressum, *Phil.* sp.
—— parvulum, *Mor. & Lyc.*

Rhynchonella, sp.?
—— Crossii, *Walker.*
—— sub-decorata, *Dav.*
Terebratula Buckmani, *Dav.*
—— fimbria, *Sow.* (young).
—— globata, *Sow.*
—— ovoides, *Sow.*
—— sp.? (numerous young).

Actæonina glabra, *Phil.* sp.
——, sp.?
Alaria armata, *Mor. & Lyc.*
—— hamulus, *Deslong.* sp.
—— hamus, *Deslong.* sp.
—— Phillipsii (?), *d'Orb.* sp.
—— sub-punctata, *Goldf.* sp.
—— trifida, *Phil.* sp.
Ceritella acuta, *Mor. & Lyc.*
——, sp. (like Sowerbyi, *Mor. & Lyc.*)?
Cerithium Beanii, *Mor. & Lyc.*
——, sp, (like costigerum, *Piette*)?
—— gemmatum, *Mor. & Lyc.*
—— limæforme (?), *Römer.*
—— quadricinctum, *Goldf.*
——, new sp.?
——, sp.?
Chemnitzia vetusta, *Phil.* sp.
Cylindrites acutus, *Sow.* sp.
—— brevis, *Mor. & Lyc.*

Cylindrites bullatus, *Mor. & Lyc.*
—— cylindricus, *Lycett.*
—— turriculatus, *Lycett.*
Delphinula (Crassostoma) Prattii, *Mor. & Lyc.*
——, sp.?
Lithodomus inclusus, *Phil.*
Monodonta Lyellii (?), *d'Arch.*
——, sp.?
Nerinæa Cotteswoldiæ, *Lycett.*
——, sp. (like small Eudesii, *Mor. & Lyc.*)?
——, sp. (like funiculus, *Desl.*)?
—— punctata, *Voltz.*
—— triplicata, *Bronn.*
—— Voltzii, *Deslong.*
Onustus, sp. (like Burtonensis, *Lycett*)?
Phasianella elegans, *Mor. & Lyc.*
—— latiuscula, *Mor. & Lyc.*
—— parvula, *Mor. & Lyc.*
—— Pontonis, *Lycett.*
—— tumidula, *Mor. & Lyc.*
Pterocera Bentleyi, *Mor. & Lyc.*
Pileolus plicatus, *Sow.* (an acute var.).
Rimula Blotii, *Deslong.*
Rissoina obliquata, *Sow.* sp.
——, sp.?
Solarium, sp. (somewhat like varicosum, *Mor. & Lyc.*)?
Trochotoma extensa, *Mor. & Lyc.*
Trochus Dunkeri, *Mor. & Lyc.*
—— bijugatus (?), *Quenst.*
Trochus Ibbetsoni, *Mor. & Lyc.*
—— Leckenbyi, *Mor. & Lyc.*
—— monilitectus, *Phil.*
—— ——, a var.
—— ornatissimus, *d'Orb.*, var. Pontonis, *Morris.*
—— spiratus, *d'Arch.*
—— ——, a var.
—— squamiger, *Mor. & Lyc.*
—— sp.?
Turbo bijugatus (?), *Quenst.*
—— gemmatus, *Lycett.*
—— sp. (like Gomondei, *Mor. & Lyc.*)?
—— ornatus (?), *Quenst.* (Littorina ornata (?), *Sow.*).
—— Phillipsii, *Mor. & Lyc.*
—— new sp.?

Serpula socialis, *Goldf.*
—— sulcata, *Sow.*
—— large sp.?
Vermicularia nodus, *Phil.*

Pseudodiadema depressum, *Ag.*
Pentacrinus, sp.? (joints).

Claws of Crustacea.

Cladophyllia, sp.?
Isastræa limitata, *Edw. & Haime.*
Thecosmilia, sp.?
Polyzoa, sp.?

Besides the foregoing, many minute young or new forms have been obtained from the Ponton shelly beds; but which, although often well preserved, it has been found impossible to identify with known species.

DENTON.

I will not attempt to trace the occurrence of these beds further north; but will incidentally draw attention to the fact that at Denton (6 miles south-west of Grantham, and 18 miles due north of Morcot), is a bed of the Lincolnshire Limestone; which has yielded nearly the same suite of fossils as the last-named place (including the fine example of *Pterocera Bentleyi* mentioned in my notice of the Collyweston Slate beds), with the addition of several univalve and bivalve forms, and some beautiful and probably new varieties of Coral.

Fossils from Lincolnshire Limestone, Denton.

Gervillia lata, *Phil.*
Hinnites velatus, *Goldf.* sp.
Lima cardiiformis, *Sow.* sp.
—— impressa, *Mor. & Lyc.*
—— Luciensis, *d'Orb.*
—— Pontonis, *Lycett.*
—— proboscidea, *Sow.* sp.
Perna quadrata, *Phil.*
Pinna cuneata, *Phil.*
Placunopsis ornatus, *Mor. & Lyc.*

Ceromya similis, *Lycett.*
Cucullæa Goldfussii, *Römer.*
Lucina Wrightii, *Oppel.*
Macrodon Hirsonensis, *d'Arch.* sp.
Myacites decurtata, *Goldf.* sp.

Pholadomya fidicula, *Sow.*
—— ovalis, *Ag.*
—— Zeitenii, *Ag.*
Trigonia hæmisphærica, *Lycett.*
—— Phillipsii, *Mor. & Lycett.*
—— striata, *Miller* (large).
Unicardium depressum, *Phil.*

Terebratula fimbria, *Sow.* (young of).
—— perovalis, *Sow.*
—— sub-maxillata, *Sow.*

Alaria armata, *Mor. & Lyc.*
Chemnitzia Wetherellii, *Mor. & Lyc.*
Natica adducta, *Phil.*
—— Leckhamptonensis, *Lycett.*
—— punctura, *Bean*, sp.
Nerinæa cingenda, *Bronn.*
——, sp. (like funiculus, *Deslong.*)?
—— triplicata, *Bronn.*
Pleurotomaria armata, *Münst.*
Pleurotomaria, sp. (allied to Marcousana, *d'Orb.*)?
—— ornata, *Defrance.*
—— sulcata, *Sow.* sp.
——, sp.?
Pterocera Bentleyi, *Mor. & Lyc.*

Serpula, new sp.*?

Acrosalenia Lycettii, *Wright.*
Clypeus Michelini, *Wright.*
Galeropygus agariciformis, *Forbes.*
Pygaster semisulcatus, *Phil.*

Calamophyllia, sp. (like Stokesii, *Edwards & Haime*)?
Montlivaltia tenuilamellosa, *Edw. & Haime.*
Thecosmilia gregaria, *M'Coy*—a var.
Genus? sp.? †
Genus? sp.?

Bourn.

From Cornbrash beds near Bourn, about 5 miles north-east of Essendine, I have the following fossils:—

Exogyra, nov. sp. (like E. virgula, *Def.*)?
Lima impressa (?), *Mor. & Lyc.*
—— rigida, *Sow.* sp.
—— rigidula, *Phil.* sp.
Ostrea (flat round large sp.?).
Pecten vagans, *Sow.*

Cardium subtrigonum, *Mor. & Lyc.*
Goniomya V-scripta, *Sow.* sp.
Homomya crassiuscula, *Mor. & Lyc.* (young).
Isocardia tenera, *Sow.*
Lucina Lycettii, *Oppel.*
Modiola gibbosa, *Sow.*
Myacites modica, *Bean*, sp.
—— securiformis, *Phil.* sp.
—— sinistra, *Ag.* sp.
—— Terquemea, *Buv.* sp.
Myopsis Jurassi, *Ag.*
Pholadomya, sp.?
Trigonia Scarburgensis, *Lycett.*
Unicardium, sp.?

Rhynchonella varians, *Schloth.*
Terebratula Bentleyi, *Morris.*
—— ——, (young examples).
—— coarctata, *Park.*
—— intermedia, *Sow.*
—— lagenalis, *Schloth.*
—— sub-lagenalis, *Dav.*

Ammonites macrocephalus, *Schloth.*

Serpula intestinalis, *Phil.*
—— tetragona, *Sow.*

Echinobrissus orbicularis, *Phil.*

Fault at Stamford‡ and Eastward.

Crossing the Welland, from the old Lincolnshire town of Stamford to the Northamptonshire parish of St. Martin, the important fault laid down in Mr. Judd's map and its consequences are encountered. Of the precise line taken by this fault, I was unaware until I saw that map, although well acquainted with its peculiar and anomalous results; which extend some miles to the east, and some of which were

* From a band, with plants and wood, similar to that overlying Slate-bed at Collyweston.

† See remarks upon these Corals by Professor Duncan, F.R.S., in discussion at the conclusion of this Paper.

‡ See Diagram of Stamford Section, Plate X. fig. 1.

described by me twenty years ago. These, however, I had not associated with *one* fault, as it is not uncommon in districts familiar to me to find beds near the brow of an escarpment much dislocated and their levels disturbed.

I have stated that the Upper Lias Clay, capped by the Northampton Sand, occurs at a considerable elevation south of Stamford, quite overtopping the town. The effect of the forces producing this fault, whilst probably elevating the beds which appear at so high a level, was to depress other beds throughout a considerable area.

Thus, at Stamford Bridge, the Upper Lias Clay is only just up to the level of the bed of the river; and in ascending the hill from this point through St. Martin's, will be passed over in succession—the Ferruginous beds of the Northampton Sand, the Lower Estuarine sands and clays, the Collyweston Slate and Lincolnshire Limestone beds, and the Upper Estuarine Clays; then again, in reiterated sequence, a great thickness of Upper Lias Clay, the Ferruginous beds (worked for ironstone at the top of the hill), the Lower Estuarine beds, the Collyweston Slate, and further on the rock beds of the Lincolnshire Limestone. So that the Collyweston Slate occurs both at the foot and at the top of the escarpment, with a difference of level of some 150 feet. (See Plate X. fig. 1.)

A cross fault has divided the sunken mass; for, in a section at the back of the Midland Railway Station (levelled out of the side of the hill), the Lincolnshire Limestone is seen in lateral juxtaposition with the Ferruginous beds of the Northampton Sand. From an excavation in the Station-yard, I obtained, from a calcareous band in the latter, fragments of a zone containing numerous bivalves, the hollows of which being filled with calcite offer a sparkling contrast to the ferruginous matrix—an effect exactly paralleled by the *Astarte-elegans* zone in ironstone quarries at Harlestone, near Northampton.

The railway passes, by a tunnel under St. Martin's, through the subsided mass of Lincolnshire Limestone, the beds of which have preserved their horizontal position, with little apparent disturbance. At the east end of the tunnel, the railway (very little above the level of the river) passes over beds of the Collyweston Slate; from which, at this point, in 1853, I obtained the beautiful and unique *Astropecten Cotteswoldiæ*, var. *Stamfordensis*, described, named, and figured, by Dr. Wright, in his Monograph upon the *Asteroidea*, published in the volume of the Palæontographical Society for 1862.

Burghley Park.

A mile east of Stamford, on the road to Pilsgate, a view of Burghley House, the palatial residence of the Marquis of Exeter, is obtained through the vista of a fine avenue of trees. In the low intervening ground, a few years ago, a temporary excavation exposed a section, to the depth of 15 feet, in horizontal beds of the Lincolnshire Limestone. At a higher elevation, the House itself, and the almost encircling ornamental sheet of water, are situated upon the clay of the Upper Lias: the ground still rises beyond, and

the beds between the Upper Lias and the Lincolnshire Limestone, in regular sequence, crop out upon the face of the escarpment.

Pilsgate.

In ascending Pilsgate Hill, half-a-mile further east, are passed over, in strange succession at this level (little above the river Welland)—the narrow outcrop of the Upper Estuarine beds, the Great Oolite Limestone (from a quarry in which many years ago I obtained fossils), the Great Oolite Clay, and further on in the village Cornbrash; with which the fault has brought into lateral contact the Lincolnshire Limestone.

Barnack.

South of the road near Barnack, is Mr. Shelton's quarry, presenting a section in the marly beds of the Lincolnshire Limestone of about 17 feet. At a little distance to the north of this quarry, and at a lower level, is a wide flat of Oxford Clay, which in Barnack, for a considerable distance, is brought into lateral contact with the Upper Lias Clay; and again, on the other side of the Welland, at Uffington, about half-a-mile to the north, the Cornbrash occurs nearly upon the same level.

Fossils from the Cornbrash at Uffington.

Avicula echinata, *Sow.*
Lima duplicata, *Sow.*
Ostrea Marshii, *Sow.* (large).
Pecten, sp.
Rhynchonella concinna, *Sow.*
—— varians, *Schloth.* sp.
Terebratula intermedia, *Sow.*
—— lagenalis, *Schloth.*
—— sub-lagenalis, *Dav.*
—— obovata, *Sow.*
Terebratula ornithocephala, *Sow.*
Chemnitzia vittata, *Phil.* sp.
Ammonites macrocephalus, *Schloth.*
Serpula tetragona, *Sow.*
Cidaris Bradfordensis, *Wright.*
Echinobrissus clunicularis, *Lhwyd.*
—— orbicularis, *Phil.* sp.
—— quadratus, *Wright.*
Holectypus depressus, *Leske* (a var.?).

Immediately south of Barnack, the road to Ufford passes through the site of the widely spread quarries whence was obtained the ancient and famous "Barnack Rag". Roman works are known to have been executed in this stone, and Roman coins bestrew the neighbourhood. Several Cathedrals and Abbeys, and most of the early churches throughout a very wide extent of country, are built of this time-enduring stone. A carved fragment from Crowland Abbey, of the 12th century, shows few symptoms of decay. These quarries have been exhausted for more than 400 years, and no section of the ancient beds exists. They may be equivalent to the worthless "Rag" beds of Weldon, Wakerley, and Little Casterton, or to the shelly beds of Ponton: from the stone of the last, the Barnack Rag lithogically is certainly frequently undistinguishable. Mr. Judd informs me, however, that the Barnack Rag immediately overlies the Northampton Sand, and I have found a corresponding shelly bed elsewhere occupying the same position; so that the Barnack Rag is possibly situated quite low down in the general section of the Lincolnshire Limestone, its peculiar character being attributable

(like the many other extreme variations in the beds of the formation) to local and exceptional conditions.

Many years ago, in the carrying out of some agricultural drainage works in fields immediately west of the old quarries, a shallow trench was excavated in the Barnack Rag; from which source, Mr. Bentley and I obtained rock specimens, and numerous, generally minute, but frequently well-preserved, fossils.

From Walcot, a hamlet to Barnack, I obtained years ago, a fine and exceptionally symmetrical specimen of Coral—*Thamnastræa concinna*, Edw. & Haime; probably an undescribed variety*.

Fossils from the "Barnack Rag," Barnack.

Anomia (Placunopsis) semistriata, *Bean.*
Avicula Braamburiensis, *Phil.*
—— echinata, *Sow.*
Gervillia ornata, *Lycett.*
Gryphæa mima, *Phil.*
Hinnites velatus, *Goldf.* sp.
Lima bellula, *Mor. & Lyc.*
—— cardiiformis, *Mor. & Lyc.*
—— duplicata, *Sow.*
—— gibbosa, *Sow.*
—— Pontonis, *Lycett.*
—— semicircularis (?), *Goldf.*
Ostrea flabelloides, *Lam.*
—— gregaria, *Sow.*
—— sulcifera, *Phil.*
——, sp.?
Pecten aratus, *Waagen.*
—— articulatus, *Schloth.*
—— lens, *Sow.*
—— personatus, *Goldf.*
—— vagans, *Sow.*, var. peregrinus, *Mor. & Lyc.*
Perna quadrata, *Phil.*
Pteroperna plana, *Mor. & Lyc.*

Arca æmula, *Phil.*
—— Prattii, *Mor. & Lyc.*
—— pulchra, *Sow.*
Astarte elegans, *Sow.*
—— fimbriata, *Walton*, M.S.
—— minima, *Phil.*
—— Pontonis, *Lycett.*
——, sp.?
Cardium incertum, *Phil.*
Cypricardia, sp.?
Cyprina Loweana, *Mor. & Lyc.*
Cytherea (Cyprina) dolabra, *Phil.*
Lucina crassa, *Sow.*
—— despecta, *Phil.*
Macrodon Hirsonensis, *d'Arch.*
Mytilus lunularis, *Lycett.*
Opis lunulatus, *Sow.* sp.
Opis similis, *Desh.* (or new sp.?).
—— smooth new sp.?
Tancredia, sp.?
Trigonia costata, *Park.*, var. pullus, *Mor. & Lyc.*
Unicardium depressum, *Mor. & Lyc.*
—— parvulum, *Mor. & Lyc.*
—— varicosum, *Sow.*

Rhynchonella Crossii, *Walker.*
—— quadriplicata, *Ziet.*
—— spinosa, *Schloth.* sp.
—— —— (young form).
Terebratula fimbria, *Sow.* (young).
—— perovalis, *Sow.*
—— simplex, *Buckm.*
—— sub-maxillata, *Sow.*

Actæonina parvula, *Römer*, sp.
——, sp.?
Alaria armata, *Mor. & Lyc.*
—— hamulus, *Deslong.* sp.
—— hamus, *Deslong.* sp.
—— trifida, *Phil.* sp.
Ceritella acuta, *Mor. & Lyc.*, var.
—— parvula, *Römer*, sp.
——, (like Sowerbyi, *Mor. & Lyc.*)?
Cerithium Beanii, *Mor. & Lyc.*
——, sp. (like costigerum, *Piette*)?
—— gemmatum, *Mor. & Lyc.*
—— limæforme (?), *Römer.*
—— quadricinctum, *Goldf.*
—— strangulatum, *d'Arch.*
——, sp.?
Chemnitzia Wetherellii, *Mor. & Lyc.*
Cylindrites brevis, *Mor. & Lyc.*
—— bullatus, *Mor. & Lyc.*
—— cylindricus, *Lycett.*
—— turriculatus, *Lycett.*
——, sp.?
Delphinula alta (?), *Mor. & Lyc.*
—— (Crossostoma) Prattii, *Mor. & Lyc.*

* See description of this specimen by Professor Duncan, F.R.S., in discussion at the conclusion of this Paper.

Delphinula, sp.?
Monodonta Lyellii (?), *d'Archiac.*
Natica Leckhamptonensis, *Lycett.*
Nerinæa cingenda, *Bronn.*
—— Cotteswoldiæ, *Lycett.*
——, sp. (like Eudesii, *Mor. & Lyc.*, young)?
——, sp. (like funiculus, *Deslong.*)?
—— Jonesii, *Lycett.*
—— punctata, *Voltz.*
—— triplicata, *Bronn.*
—— Voltzii, *Deslong.*
——, sp.?
Onustus, sp. (like Burtonensis, *Lycett*)?
Phasianella conica, *Mor. & Lyc.*
—— elegans, *Mor. & Lyc.*
—— parvula, *Mor. & Lyc.*
—— Pontonis, *Lycett.*
—— tumidula, *Mor. & Lyc.*
—— variata (?), *Lycett.*
——, sp.?
Pleurotomaria, sp. (like composita, *Mor. & Lyc.*)?
Rissoina obliquata, *Sow.* sp.
Solarium, sp. (something like varicosum, *Mor. & Lyc.*)?
Trochus Dunkeri, *Mor. & Lyc.*
—— bijugatus (?), *Quenst.*
—— Ibbetsoni, *Mor. & Lyc.*
—— Leckenbyi, *Mor. & Lyc.*
—— monilitectus, *Phil.*
—— ——, a var.
—— ornatissimus, *d'Orb.*, var. Pontonis, *Morris.*
—— spiratus, *d'Arch.*
—— ——, var.
Trochus squamiger, *Mor. & Lyc.*
——, sp.?
Turbo bijugatus (?), *Quenst.*
—— gemmatus, *Lycett.*
—— ornatus (?), *Quenst.* (Littorina ornata, *Sow.*)?
—— Phillipsii, *Mor. & Lyc.*
——, sp.?

Ammonites Blagdeni (?), *Sow.* (young).
—— Murchisonæ (?), *Sow.* (young).

Serpula plicatilis, *Goldf.*
—— socialis, *Goldf.*
—— sulcata, *Sow.*
Vermicularia nodus, *Phil.*

Acrosalenia Lycettii, *Wright.*
Cidaris Fowleri, *Wright.*
—— Wrightii (?), *Desor.*
Pseudodiadema depressum, *Ag.*
Pentacrinus subsulcatus (?), *Goldf.* (joints).

Crustacea (claws).

Isastræa limitata, *Edw. & Haime.*
Montlivaltia, sp.?
Thecosmilia gregaria, *Edw. & Haime.*
Thamnastræa concinna, *Edw. & Haime* (a remarkable variety)*.

Hybodus? (dorsal spine).
Strophodus magnus, *Ag.* (palates).
—— subreticulatus, *Ag.* (palates).

In addition to the fossils tabulated above, many other minute specimens have been obtained from the Barnack Rag; which, from their being new or young forms (although frequently well preserved), it has been found impossible to identify with described species.

Ufford.

In ascending the hill into Ufford, the almost tiring reiterated series of all the beds from the Lias upwards to the Great Oolite Limestone inclusive is again crossed. At less than a mile east of Ufford, and at a very slightly lessened elevation, are quarries in the Lincolnshire Limestone. Under about 16 feet of very oolitic stone, are 2 feet 6 inches of slates and "poltids," which repose upon the Lower Estuarine Sands,—seen to the thickness of 9 feet, disposed in thin seams, exhibiting much variation in colour, and containing horizontal and vertical plant-markings.

Helpstone.

At a little distance east of this, and within an area not greatly

* See Professor Duncan's remarks in the "Discussion."

exceeding half-a-mile in radius, the various formations assume positions exceedingly anomalous and complicated. On the high ground of Helpstone Heath, is a large quarry in the Lincolnshire Limestone; which is exposed to the thickness of 18 to 20 feet. All the beds are very oolitic, and one is very much inclined from false-bedding: this is separated, by a horizontal flaggy bed, from another bed as much inclined in the reverse direction. No Slate is found here; but a thin band of blue clay separates the Limestone from the Lower Estuarine Sands beneath.

Immediately north of this quarry, is Knight's brickfield. Here, beneath some 10 or 12 feet of oolitic limestone, and separated from it by a foot of sandy clay, are about 18 feet of the Lower Estuarine Sands—in very thin and variegated layers, much inclined to the north (in the direction of the neighbouring escarpment), and containing the characteristic plant-bed in one of the upper bands. Beneath, are ironstone beds of the Northampton Sand, not exposed, but probably having a thickness of 10 or 12 feet. These overlie the clay of the Upper Lias, which is worked for bricks, and is at a considerable elevation above the neighbouring low lands. A few hundred yards to the north of the brick-pit, and at a slightly lower elevation, a temporary opening, a few years ago, disclosed a very solid and shelly rock of Cornbrash: a little to the south-east of this point again, is the abandoned Old Coppice Green parish pit, in Lincolnshire Limestone, the beds of which are coarsely oolitic and false-bedded; while, at the bottom of the hill, at a much lower level, right and left of the southern entrance to the village of Helpstone, are quarries in the Great Oolite Limestone, which is surmounted by a thin covering of Great Oolite Clay, with layers of *Ostrea subrugulosa* in a normal horizontal position.

Half a mile further east than the Old Coppice Green pit, is the most eastern point of the Lincolnshire Limestone area in this direction; and about two miles further, in the parish of Marholme, or in that of Walton, is the last that is to be seen of the Limestones of the Great Oolite.

In directions, north, north-east, east, and south-east, of this locality, all these Northamptonshire beds dip, and are lost, under the extended field of the Oxford Clay; which constitutes the great low flat of the Lincolnshire, the Cambridgeshire, and the Huntingdonshire Fens.

St. Martin's, Stamford.

On the summit of the hill south of and over-looking Stamford (to which I have already twice alluded), are the Marquis of Exeter's excavations for ironstone, just within the Burghley Park Wall. (See Pl. X. fig. 1).

At the top of the section, in patches, answering to the surface contour, appears the Collyweston Slate, weathered into slate from lying so near the surface: beneath this, are the Lower Estuarine Sands and Clays, having a thickness of from 6 to 7 feet, the lowest band containing vertical plant-markings: immediately under these,

is the "Best Black" ironstone (cellular), then the "Second," together from 4 to 5 feet in thickness: a calcareous band of 6 inches comes in here; and below it, succeed—the "Bottom" ironstone (so called), also cellular, 2 feet; a green ferruginous bed, 1½ foot; and a thin ferruginous band, "full of water," and containing small pebble-like nodules (as in the same bed in different ironstone quarries about Northampton), 9 inches; and under all the Upper Lias. As far as I have been able to ascertain, no fossils have been found in these beds.

Section at Burghley-Park Ironstone-Quarry.

	ft.	in.	ft.	in
1. Soil and Rubble, with patches of Collyweston Slate at bottom			2	6
2. Lower Estuarine Series—				
a. Sand—pale yellow, becoming redder towards the bottom	5	0		
b. Blue clay. with vertical plant-markings	1	6		
3. Ferruginous Beds—	——		6	6
a. "Best Black" Ironstone, cellular	2	0		
b. "Second"—less cellular, and more sandy	2	0		
c. Calcareous band	0	6		
d. "Bottom" ironstone, cellular	2	0		
e. Green ferruginous stone, about	1	6		
f. Thin red ferruginous band, with pebble-like nodules (as at Duston and Kingsthorpe)	0	9		
	——		8	9
(The last two beds were "full of water.")				
4. Upper Lias Clay.				

Within a few hundred yards to the west, are Lumby's Terracotta Works. A band in the Lower Estuarine Clays supplies an excellent material (mixed with some other ingredients) for this manufacture, and a very durable cream-coloured *terra-cotta* is produced. Similar clay is found at other places in the same bed, and is largely used in the well-known Terra-cotta Works of Mr. Blashfield of Stamford.

At a quarter of a mile further south, on the roadside opposite Whincup's Farm, is the old stone quarry of the abolished Trustees of the Great North Road. The Lincolnshire Limestone is here seen in section to the depth of 18 feet: it is divided into eight distinct beds, varying in mineral condition; some are marly and others oolitic, those near the bottom having much of the character of Barnack Rag, being coarsely oolitic, and containing numerous small shells.

Section in the Lincolnshire Limestone in the Old-Road Pit, near Whincup's Farm.

	ft.	in.
1. Rubble and broken limestone	1	6
2. Compact cream-coloured marly limestone, in thin layers much broken	3	0
3. Soft white marly limestone, surfaces and angles rounded by weathering (*Lima bellula*, Mor. & Lyc.)	2	6
4. Hard cream-coloured limestone, rather oolitic	3	0
5. Oolitic limestone, like the "cale" of Collyweston	2	0
6. Soft crumbling "caley" oolite	2	6
7. "Rag" bed—coarse oolite, containing numerous shells, *Lucina Wrightii*, Oppel, *Opis*, &c.	1	6
8. Hard oolitic stone—not bottomed	2	6

Whittering.

A mile south of Whincup's Farm, the road descends a small valley, crosses the White Water brook upon the Upper Lias, and, after passing for a mile over various beds of the Lincolnshire Limestone, traverses the area of the old "Whittering Pendle" quarries. These were very shallow, and, having fallen into disuse, the old familiar pits have long since been levelled down and ploughed over. The "Whittering Pendle," although it has been considered identical with the Collyweston Slate, is very different in its mineral character, being very hard, crystalline, and sometimes almost cherty in texture. It was excavated in large irregular slabs, varying in thickness from one inch to two inches, and was used, without being squared, for the door-slabs and rough floors of cottages, for back-kitchens, &c.

The fossils gathered from this bed are generally characteristic of the Lincolnshire Limestone; but I must particularly notice a specimen taken by myself from the section nearly thirty years ago, and labelled as a Coral during all that time, but which last July was identified by Professor Phillips, F.R.S., as the spadix or fruit of *Aroides Stutterdi*, Carruth., an Arum-like plant, only previously known, I believe, as occurring in the Stonesfield Slate, and described by Mr. Carruthers in the 'Geological Magazine' for April, 1867.

Fossils from the "Whittering Pendle."

Gervillia, sp.?
Hinnites abjectus, *Phil.*
—— velatus, *Goldf.* sp.
Lima cardiiformis, *Sow.*
—— impressa, *Mor. & Lyc.*
—— Pontonis, *Lycett.*
Pecten aratus (?), *Waagen.*
—— lens (?), *Sow.* (or new sp.?).
—— personatus, *Goldf.*
Perna quadrata, *Phil.*
—— rugosa, *Goldf.*
Pteroperna, sp?

Lucina Bellona, *d'Orb.*
—— Wrightii, *Oppel.*
Macrodon Hirsonensis, *d'Arch.* sp.
Modiola, sp.?

Belemnites Bessinus, *d'Orb.*

Aroides Stutterdi, *Carruth.* (spadix).

Wansford, Wansford Tunnel, and Huntingdonshire.

The Lincolnshire Limestone continues to be the surface rock for two miles and a half south of Whittering, and is crossed in that space by two valleys, which deepen down to the Upper Lias. It may be seen in a large quarry at Thornhaugh, and again in the road-cutting on the hill overlooking Wansford and the valley of the Nene; which is here the line of demarcation between Northamptonshire and Huntingdonshire.

The river flows over the Upper Lias (generally covered with alluvium). The famous Haycock Inn and the southern half of the village stand on the Northampton Sand. At a higher level, near Wansford Mill, many years ago, a quarry was opened in the Lincolnshire Limestone, in which, beneath a considerable thickness of marly beds (some blue-hearted), was a zone of very hard crystalline limestone, almost made up of small and comminuted shells: at the

bottom of the section, some feet of the Lower Estuarine Sands were exposed.

Half a mile south of this spot, is a very large quarry, called the "Sheep-pens" quarry. The section here exposes a thickness of about 23 feet of the Lincolnshire Limestone, consisting of some seven beds, which display the usual variable characters; overlying a band of two feet of flaggy limestone, disposed in courses of about 2 inches thickness, and containing numerous plants and *Ferns.* Under this, is a band of about 6 inches of Slate, reposing upon a "reddish sand," Lower Estuarine.

Section at the Sheep-pens Quarry, near Wansford Tunnel.

	ft.	in.
1. Rubble and broken limestone	3	6
2. Very hard brown limestone, somewhat crystalline, a capital building-stone, and makes good lime	4	0
3. Soft friable limestone	2	6
4. Compact marly limestone, having a glistening fracture	1	6
5. Sand	0	6
6. Brownish soft bed	1	6
7. Flaggy blue-hearted limestone	1	0
8. "The hard"—a fossiliferous limestone, having a glistening fracture, and sometimes blue-hearted	6	0
9. Hard flaggy limestone, somewhat arenaceous, containing *plants* and *ferns* and a few shells, and sometimes blue-hearted, in layers of two inches	2	0
10. Slate, in small "potlids"	0	6
11. Ruddy sand—Lower Estuarine.		

At a little more than a quarter of a mile beyond this quarry, is the Wansford Railway Tunnel, which passes for one third of a mile, west and east, through beds of the Lincolnshire Limestone. At its western entrance, are the ancient "Red Stone" or "South Pit" quarries, not now worked. Here the stone is a very red, coarse, shelly oolite: it was formerly much in request for the walls of locks, mill-courses, and other hydraulic work. The fossils obtained from this stone correspond very nearly with those yielded by the Ketton and Casterton freestones, with the addition of *Patella rugosa,* some peculiar *Corals,* and a fine example of *Palæozamia pectinata.*

Fossils from the Old "Red Stone" Quarry, Wansford Tunnel.

Ostrea flabelloides, *Lam.*
—— gregaria, *Sow.*

Arca Prattii, *Mor. & Lyc.*
Astarte elegans, *Sow.*
Cucullæa oblonga, *Sow.*
Lucina Bellona, *d'Orb.*
—— Wrightii, *Oppel.*
Homomya crassiuscula, *Mor. & Lyc.* (young).
Myoconcha crassa, *Sow.*
Pholadomya, large sp.?
Trigonia spinulosa (?), *Young & Bird.*
Terebratula perovalis, *Sow.*

Natica Leckhamptonensis, *Lycett.*
Nerinæa triplicata, *Bronn.*
—— Voltzii, *Deslong.*
Patella rugosa, *Sow.*

Latimæandra Davidsoni, *Edw. & Haime.*
—— Flemingi, *Edw. & Haime.*
Thecosmilia gregaria, *M'Coy* (a var.).

Palæozamia pectinata, *Brong.*
Wood.

T 2

At the eastern end of the Tunnel, the Lincolnshire Limestone appears in massive beds of hard, compact, marly, blue-hearted limestone. The crown of the Tunnel arch reaches up into the lower beds of the Upper Estuarine Clays, which here, as elsewhere, are characterized by the basal ferruginous band. Many tons of this band (which assumes an almost septarian character in places) were, some years ago, experimentally smelted by the late Marquis of Huntley, and a good quality of pig-iron was produced.

The Great Oolite Limestone surmounts the Upper Estuarine Clays, and forms the surface-rock over the Tunnel; at a short distance south, it is overlain by the Great Oolite Clay; and this, in turn, in less than half a mile in the same direction, by the Cornbrash.

Thus (as I have shown) upon a line between Stamford Field, on the north, and a point half a mile south of the Wansford Tunnel, a distance of about 8 miles, the Lincolnshire Limestone is the prominent surface rock; and at each end of this line, is an escarpment, presenting a perfect sequence of beds from the Cornbrash to the Upper Lias inclusive, in which the distinct individuality of the beds of the Great Oolite Limestone and of the Lincolnshire Limestone is unmistakably demonstrated, and the true place of the latter formation in that sequence as certainly determined.

East of the Wansford Tunnel, on the Huntingdonshire side, and at Castor on the Northamptonshire side, of the river Nene, are quarries in the Lincolnshire Limestone; and from these, I have numerous fossils: those from Castor include *Goniomya literata*, Sow. sp., &c.

Fossils from the Lincolnshire Limestone, South of the Nene, near Wansford, Hunts.

Shelly and Freestone Beds.

Hinnites abjectus, *Phil.*
—— velatus, *Goldf.* sp.
Lima bellula, *Mor. & Lyc.*
—— punctata, *Sow.*
Ostrea flabelloides, *Lam.* (young).
—— gregaria, *Sow.*
——, sp.? (young), mimetically marked.
——, sp?
Pecten articulatus, *Schloth.*
—— demissus, *Phil.*
——, small smooth sp.?
——, new sp.?
Perna rugosa, *Goldf.* (young).
Pteroperna costatula, *Deslong.* (young).
—— plana, *Mor. & Lyc.* (young).
Trichites nodosus, *Lycett.*

Arca æmula, *Phil.*
—— Prattii, *Mor. & Lyc.*
—— pulchra, *Sow.*
——, sp. (like Kilverti, *Mor. & Lyc.*)?
——, sp.?
Astarte depressa, *Mor. & Lyc.*
—— elegans, *Sow.*
—— excavata, *Sow.*, var. compressiuscula, *Mor. & Lyc.*
—— minima, *Phil.*
—— recondita, *Phil.*
—— rhomboidalis, *Phil.* sp. (young).
——, sp.?
Cucullæa oblonga, *Sow.*
Homomya crassiuscula, *Mor. & Lyc.* (young).
Lucina Bellona, *d'Orb.*
—— despecta, *Phil.*
—— Wrightii, *Oppel.*
Macrodon Hirsonensis, *d'Arch.* sp.
Modiola gibbosa, *Sow.*
Myoconcha crassa, *Sow.*
Mytilus lunularis, *Lycett.*
Opis lunulatus, *Sow.* sp.
—— similis, *Desh.* (or new sp.?).
——, smooth new sp.?
Pholadomya fidicula, *Sow.*
——, large new sp.?
——, sp.?

Trigonia compta, *Lycett.*
—— spinulosa (?), *Young & Bird.*

Rhynchonella Crossii, *Walker.*
——, new sp.?
Terebratula carinata, *Sow.*, or emarginata, *Sow.*? (young).
—— fimbria, *Sow.* (young).
—— ovoides, *Sow.*
—— perovalis, *Sow.*

Actæonina glabra, *Phil.*
——, sp.?
——, sp.?
Alaria trifida, *Phil.*
——, sp. (smooth with spines)?
Cerithium Beanii, *Mor. & Lyc.*
—— gemmatum, *Mor. & Lyc.*
—— quadricinctum, *Goldf.*
Cylindrites bullatus, *Mor. & Lyc.*
—— turriculatus, *Lycett.*
Delphinula (Crossostoma) Prattii, *Mor. & Lyc.* (a var.).
Monodonta Lyellii (?), *d'Arch.*
——, sp. (like Labadyei, *d'Arch.*)?
Natica Leckhamptonensis, *Lycett.*
Nerinæa Cotteswoldiæ, *Lycett.*
—— gracilis, *Lycett.*
—— Jonesii, *Lycett.*
—— punctata, *Voltz.*
Nerinæa triplicata, *Bronn.*
—— Voltzii, *Deslong.*
Patella rugosa, *Sow.*
Phasianella conica, *Mor. & Lyc.*
Solarium, sp. (like varicosum, *Mor. & Lyc.*)?
Trochus Dunkeri (?), *Mor. & Lyc.*
—— Ibbetsoni, *Mor. & Lyc.*
—— Leckenbyi, *Mor. & Lyc.*
—— monilitectus, *Phil.*
—— spiratus, *d'Arch.*
—— —— (a var.).
——, new sp.
Turbo bijugatus (?), *Quenst.*
—— gemmatus, *Lycett.*
—— ornatus (?), *Quenst.*
—— Phillipsii, *Mor. & Lyc.*
——, sp.?

Serpula sulcata, *Sow.*

Acrosalenia Lycetti, *Wright.*

Latimæandra Davidsoni, *Edw. & Haime.*
—— Flemingi, *Edw. & Haime.*
Thecosmilia gregaria, *M'Coy* (a var).

Acrodus or Hybodus? (tooth).
Strophodus subreticulatus, *Ag.* (palate).

Marly Beds.

Avicula Münsteri, *Goldf.*
Lima cardiiformis, *Sow.*
—— duplicata, *Sow.*
—— Pontonis, *Lycett.*
—— Rodburgensis, *Lycett,* M.S.
—— semicircularis (?), *Goldf.*
——, sp.?
Pecten demissus, *Phil.*
—— ——, var. Gingensis, *Quenst.*
Pinna cuneata, *Phil.*

Ceromya Bajociana, *d'Orb.*
—— similis, *Lycett.*
Cucullæa cancellata, *Phil.*
Macrodon Hirsonensis, *d'Arch.* sp.
Modiola Sowerbyana, *d'Orb.*

Rhynchonella plicatella, *Sow.*
Terebratula perovalis, *Sow.*
—— sub-maxillata, *Sow.*

Natica Leckhamptonensis, *Lycett.*
—— —— (large variety, with beautifully punctated surface).

Annulated annelide tube *.
Serpula intestinalis, *Phil.*

Crustacean claw.

Isastræa limitata, *Edws. & Haime.*
Thamnastræa, sp.?

Hybodus (dorsal spine).

Coniferous wood.

Alwalton to Peterboro'—Stilton.

The southern escarpment of the Nene Valley, between Chesterton and Woodstone (half a mile south-west of Peterboro') exposes beds of Cornbrash and Great Oolite Clay and Limestone. The last is traversed in places by a shelly and crystalline band, the stone of which

* Found also in Great Oolite Limestone of Blisworth, in Ironstone beds of Northampton Sand at Duston, and near Banbury.

takes a good polish, and, having been quarried at Alwalton from ancient times, has been called "Alwalton Marble." The long slender disengaged shafts which decorate the exquisite and unique Early English front of Peterboro' Cathedral (dating from the 13th century) were originally composed of this "marble."

From these beds, and from a small patch of Cornbrash near Stilton, I have obtained the following fossils, those from the Cornbrash being in exceedingly fine preservation :—

Cornbrash Fossils.

Anomia semistriata, *Bean.*
Avicula echinata, *Sow.*
Lima duplicata, *Sow.* sp.
—— impressa, *Mor. & Lyc.*
—— læviuscula, *Sow.* sp.
—— pectiniformis, *Schloth.* sp.
—— rigida, *Sow.* sp.
—— rigidula, *Phil.* sp.
Ostrea (Exogyra) lingulata, *Walton*, M.S.
—— Marshii, *Sow.*
——, large flat smooth sp.
——, several examples of different sp. (mimetically marked by contact with Trigoniæ).
Pecten anisopleurus, *Buv.*
—— articulatus, *Schloth.*
—— annulatus, *Sow.*
—— demissus, *Phil.*
—— inæquicostatus, *Phil.*
—— lens, *Sow.*
—— Michelensis, *Buv.*
—— vagans, *Sow.*
—— ——, (a var.).
——, new sp.?
——, new sp.?

Cardium cognatum, *Phil.*
Cypricardia caudata, *Lycett.*
Goniomya V-scripta, *Sow.* sp.
Homomya crassiuscula, *Mor. & Lyc.*
—— gibbosa, *Sow.* sp.
Isocardia tenera, *Sow.*
Lucina striatula, *Buv.*
Modiola gibbosa, *Sow.*
—— imbricata, *Sow.*
—— Lonsdalei, *Mor. & Lye.*
—— Sowerbyana, *d'Orb.*
Myacites calceiformis, *Phil.* sp.
—— decurtata, *Goldf.* sp.
—— recurva, *Phil.* sp.
—— securiformis, *Phil.* sp.
—— sinistra, *Ag.* sp.
——, new sp.?
Pholadomya acuticosta, *Sow.*
Pholadomya deltoidea, *Sow.*
—— lyrata, *Sow.*
—— Phillipsii, *Morris**.
Trigonia Scarburgensis, *Lycett.*

Rhynchonella Morieri, *Dav.*
—— concinna, *Sow.*
—— obsoleta, *Sow.*
—— varians, *Schloth.*
Terebratula Bentleyi, *Morris.*
—— ——, a variety.
—— coarctata, *Park* †.
—— intermedia, *Sow.*
—— lagenalis, *Schloth.*
—— sub-lagenalis, *Dav.*
—— maxillata, *Sow.*
—— obovata, *Sow.*
—— ornithocephala, *Sow.*
——, undescribed sp.

Bulla, large new sp.
Chemnitzia simplex, *Mor. & Lyc.*
—— vittata, *Phil.*
——, sp.?
Dentalium, new sp.
Pleurotomaria granulata, *Sow.* sp.

Ammonites Herveyi, *Sow.*
—— macrocephalus, *Schloth.*
—— modiolaris, *Lhwyd.*
Belemnites, new sp.?

Serpula intestinalis, *Phil.*
—— squamosa, *Bean.*
—— tetragona, *Sow.*

Clypeus Mülleri, *Wright.*
Echinobrissus clunicularis, *Lhwyd.*
—— orbicularis, *Phil.* sp.
Holectypus depressus, *Leske.*

Icthyosaurus—teeth, vertebræ, and other bones.
——, small individual—jaws and bones.

* One large example has a brilliant nacre.

† Found in Great Northern Railway cutting north of Peterboro' (Northamptonshire). Presented to me by Mr. Bentley, Feb. 5, 1873.

Plesiosaurus—vertebræ and other bones.
Teleosaurus—jaws and teeth, dorsal scute, vertebræ, &c.
Numerous Crocodilian and other Saurian teeth.

Asteracanthus verrucosus, *Eger.*—large dorsal spine.
Lepidotus—scales.
Pycnodus Bucklandi, *Ag.*—teeth.
Strophodus magnus, *Ag.*—palates.
—— subreticulatus, *Ag.*—palates.

Coniferous wood.

Great Oolite Fossils.

Avicula echinata, *Sow.*
—— Münsteri, *Goldf.*
Lima impressa, *Mor. & Lyc.*
—— semicircularis, *Goldf.*
Ostrea Sowerbyi, *Mor. & Lyc.*
—— sub-rugulosa, *Mor. & Lyc.*
——, sp.?
Pecten annulatus, *Sow.*
—— demissus, *Phil.*
—— lens, *Sow.*
——, large species?
Pteroperna costatula, *Deslong.*

Astarte, small sp.?
Cardium Buckmani, *Mor. & Lyc.*
—— cognatum, *Phil.*
Gresslya peregrina, *Phil.*
Homomya crassiuscula, *Mor. & Lyc.*
—— Vezelayi, *d'Arch.* sp.
Isocardia, sp.?
Modiola imbricata, *Sow.*
—— Sowerbyana, *d'Orb.*
Myacites decurtata, *Phil.* sp.
Pholadomya deltoidea, *Sow.*
—— lyrata, *Sow.*
—— Phillipsii, *Morris.*
—— socialis, *Mor. & Lyc.*
——, new sp.? with irregular costæ *.
Trigonia Moretoni, *Mor. & Lyc.*
——, sp.?
Unicardium, sp.?

Rynchonella concinna, *Sow.*
—— obsoleta, *Sow.*
Terebratula intermedia, *Sow.*
—— maxillata, *Sow.*
—— ornithocephala, *Sow.* (or new sp.?).

Natica, sp.?
Nerita minuta, *Sow.*
Pleurotomaria, sp.?

Ammonites bullatus, *d'Orb.*
Belemnites, sp.?
Nautilus Baberi, *Mor. & Lyc.*
—— hexagonus (?), *Sow.*
—— subtruncatus, *Mor. & Lyc.*

Serpula oblique-striata, *Lycett.*
——, sp.?

Clypeus Mülleri, *Wright.*
Echinobrissus clunicularis, *Lhwyd.*
—— Griesbachii, *Wright.*
—— Woodwardi, *Wright.*
Holectypus depressus, *Leske.*

Glyphea rostrata, *Phil.*

Crocodilian teeth.
Ichthyosaurus—vertebræ and teeth.
Plesiosaurus—vertebræ and other bones.

Hybodus dorsalis, *Ag.*—large spine.
——, sp.?—dorsal spine.
Lepidotus, sp.?—jaw.
——, sp.?—large scales.
Pycnodus Bucklandi, *Ag.*—palates and teeth.
Strophodus magnus, *Ag.*—palates.
—— subreticulatus, *Ag.*

Wood.

A little south of Castor, the Lincolnshire Limestone is only thinly shown; and a little further south, the Upper Estuarine and the Lower Estuarine have once more come together, without the intervention of the Lincolnshire Limestone, which has thinned away and disappeared: the same phenomena are repeated at the opposite, the Huntingdonshire side of the river, at Water Newton; and here, therefore, we may place the limit of the Eastern extension of the formation.

* Found also at Essendine and Danes' Hill, and near Northampton—all in Great Oolite Limestone.

Southern Escarpment of the Nene Valley.

West of Wansford Tunnel, near Elton, the Lincolnshire Limestone, in like manner, has disappeared from the southern escarpment of the Nene Valley; but this has received the addition of the Oxford Clay (based by the Kelloway Rock) as the summit bed, and continues unaltered as to its constituent beds (represented in the diagram of vertical sections *) as far as Higham Ferrers (18 miles); near to which town, its upper portion, consisting of the Oxford Clay, Kelloway Rock, and Cornbrash, trends southward, by Rushden and Wymmington, into Bedfordshire, and, crossing the valley of the Ouse, passes on into Buckinghamshire, and away.

Oundle.

At Oundle (the eastern extremity of my horizontal section †), the escarpment upon either side of the Nene valley is precisely the same. No trace of the Lincolnshire Limestone is found, although at Weldon, only six miles distant due west, it has a thickness exceeding thirty feet; so that the thinning away of that formation in the short intervening space must have been very rapid.

The Oxford Clay caps the high ground of that intervening space, and extends over a considerable tract west and south-west of the same; while at Benefield, three miles west of Oundle, and also on the line of my horizontal section, the Cornbrash and great Oolite beds are also accessible.

Fossils from Benefield.

Cornbrash.

Rhynchonella Morieri, *Dav.*
Terebratula lagenalis, *Schloth.*
—— obovata, *Sow.*

Great Oolite.

Cyprina Loweana, *Mor. & Lyc.*
Isocardia tenera, *Sow.*
Modiola imbricata, *Sow.*
Pinna ampla, *Sow.*
Terebratula intermedia, *Sow.*
—— maxillata, *Sow.*
Clypeus Mülleri, *Wright.*

In a quarry in the Great Oolite Limestone near Oundle, long since closed, were formerly obtained specimens of a beautiful little *Ophiurella*, named by Dr. Wright, *O. Griesbachii*, in compliment to the late well-known veteran Northamptonshire geologist of that name.

Section in Great Oolite Limestone, Oundle.

	ft.	in.		ft.	in.
1. "Lime Earth"—a cream-coloured calcareous argillaceous material, sometimes used for mortar without burning...				2	0
2. "Pendle"—very hard and glistening, splits into thin flags or slates (*Modiola imbricata*, Sow.)				0	6
3. Blue Clay..	0	9	to	1	0
4. Calcareo-argillaceous bed, full of *Ostrea Sowerbyi*, Mor. & Lyc., burnt for lime..	1	0	to	1	3
5. Very shelly hard limestone, in thin layers				0	9

* See fig. 4, II., page 283.

† Plate X. fig. 2.

	ft.	in.
6. "Best building-stone"—hard crystalline blue-hearted limestone, full of comminuted shells, worked into lintels and sills of windows, quoinings, &c.	3	0
7. Marly limestone, full of shells	3	0
8. Very hard blue-hearted crystalline limestone, full of comminuted shells (small *Pteroperna*), used for road-metal	2	6
9. Upper Estuarine Clays.		

Fossils.

Lima cardiiformis, *Sow.*
——, sp. (like, but not, duplicata, *Sow.*) ?
Ostrea Sowerbyi, *Mor. & Lyc.*
—— sub-rugulosa, *Mor. & Lyc.*
Pecten lens, *Sow.*
Pteroperna, sp. ?
Modiola imbricata, *Sow.*
Trigonia Moretoni, *Mor. & Lyc.*
Rhynchonella concinna, *Sow.*
Belemnites (small).
Strophodus magnus, *Ag.* (palate).
Ophiurella Griesbachii, *Wright.*

THRAPSTONE TO NORTHAMPTON.

North of Thrapstone and Islip, the high ground has a thin capping of Cornbrash; beneath which, upon a western escarpment, crops out the same sequence of beds as that with which I commenced my descriptions, viz.—

Great Oolite Limestone.
Upper Estuarine Series.
Lower Estuarine Series, } Northampton Sand.
Ferruginous Beds, }
Upper Lias Clay.

And the same sequence again and again occurs throughout the district intervening between Islip and Northampton.

Great Oolite Fossils from Thrapstone.

Cypricardia nuculiformis, *Römer.*
Modiola imbricata, *Sow.*
Ostrea Sowerbyi, *Mor. & Lyc.*
Rhychonella concinna, *Sow.*
Terebratula intermedia, *Sow.*
—— maxillata, *Sow.*
Echinobrissus clunicularis, *Lhwyd.*

Cornbrash Fossils from Islip.

Cypricardia caudata, *Lycett.*
Modiola Lonsdalei, *Mor. & Lyc.*
Myacites decurtata, *Goldf.* sp.
—— securiformis, *Phil.* sp,
——, sp. ?
Terebratula lagenalis, *Schloth.*
—— obovata, *Sow.*
——, new sp.
Echinobrissus orbicularis, *Phil.* sp.

The Ferruginous beds become thicker and richer at Woodford, Cranford, Finedon, Wellingboro', and other neighbouring places. The quarrying of ironstone has greatly increased in Northamptonshire during 1872; a quantity exceeding 20,000 tons being at this time (November, 1872) weekly raised in the county.

CONCLUSION.

The geological phenomena of the numerous localities described have served, I would submit, to establish the following Propositions:—

I. That the Upper Estuarine Series of Sands and Clays (subject to local denudation) ranges over the whole of the wide reach of country described, and is everywhere immediately subjacent to the Limestone beds of the Great Oolite, when these are present.

II. That the Lower Estuarine Series has an equally wide spread, and as persistently overlies the more or less Ferruginous beds of the Northampton Sand.

III. That, throughout the wide range of the Lincolnshire Limestone, the place of that Limestone is immediately below the Upper Estuarine Series (where not denuded), and immediately above the Lower Estuarine Series.

IV. That, therefore, necessarily, the Limestone of Kingsthorpe and other high localities about Northampton, and the extensive Limestone now known as the Lincolnshire Limestone, are distinct, and belong to different geological periods.

The *palæontological* evidence also necessitates the last Proposition, and determines further the geological period to which each of these distinct formations belongs—and this, not upon the presence of one or a few fossils only, but upon the *general facies* which the organic contents of these formations severally present:—

I. Organic forms obtained from the Limestone overlying the Upper Estuarine Series in the neighbourhood of Northampton are as a group so identical with those obtained from beds in the same position in the neighbourhood of Stamford, that, if a number of fossils from one locality were asserted to have come from the other locality, and *vice versâ*, the assertion could not be disputed on palæontological grounds; and the general character of these forms would indicate that they, and therefore the beds in which they occur, belong to the Great-Oolite period.

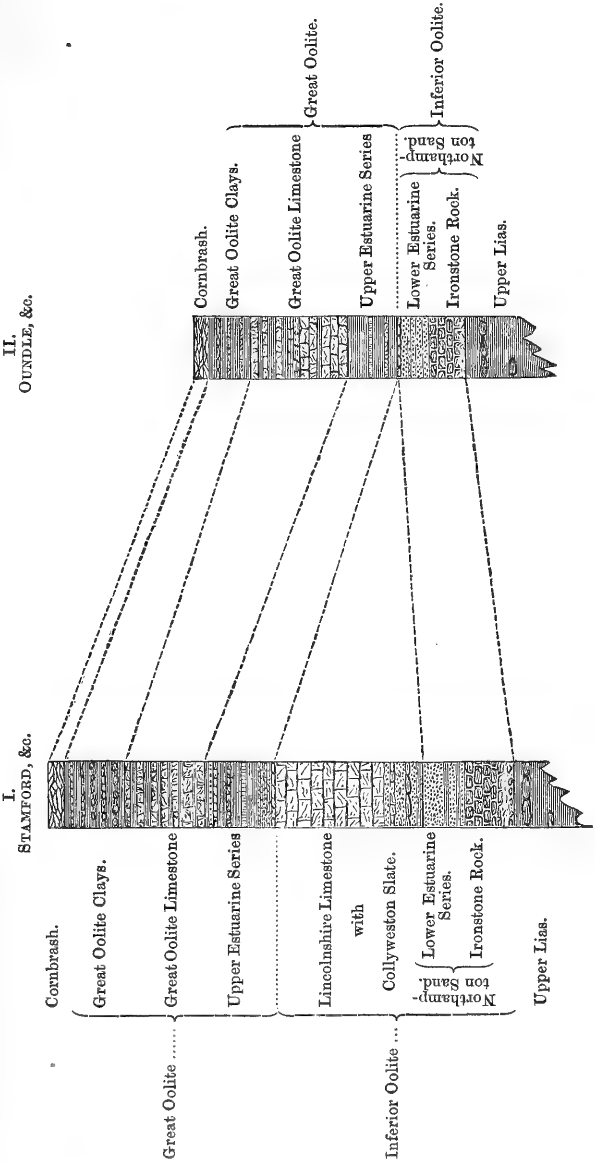
II. The organic forms obtained from the Lincolnshire Limestone comprise an altogether different group. Few of them are identical with fossils of the Great Oolite Limestone, while many are identical with fossils which occur in the Ferruginous beds of the Northampton Sand; and their general character indicates that they, and therefore the Lincolnshire Limestone, are of the period of the Inferior Oolite.

These Propositions proven, I contend that Physical Geology and Palæontological Geology combine to afford indisputable evidence of the truth of the conclusions which I pre-stated in my Introduction.

Therefore—the General Section of the north-eastern portion of the Northern Division of Northamptonshire, will be represented in the Diagram I., which *includes* the Lincolnshire Limestone; while the General Section of the south-western portion of that Division, will be represented in the Diagram II., which *excludes* that formation*.

* See fig. 4—opposite page.

Fig. 4.—*Sections illustrating the Relations of the Lincolnshire Limestone to the Northamptonshire Oolite.*



Maximum Thicknesses of Beds within the Area described.

			feet.
Oxford Clay	uncertain.		
Cornbrash			15
Great Oolite—Clay		20 feet.	
" Limestone		25 "	
" Upper Estuarine		33 "	
		——	78
Inferior Oolite—Lincolnshire Limestone		75 feet.	
" Northampton Sand—			
Lower Estuarine	18 feet.		
Ferruginous beds	60 "		
	——	78 "	
		——	153
			——
			246

A few words as to the extent of the area occupied by the Lincolnshire Limestone. It ranges through the whole of the county of Lincoln, stretching into South Yorkshire on the north, and through Rutland into Northamptonshire on the south. The length of this outcrop (three fourths of which is in Lincolnshire) is about 110 miles. In Northamptonshire, its greatest apparent width across the strike is about 16 miles. It attains to its greatest thickness in Lincolnshire, exceeding near Sleaford 200 feet. Mr. Judd (who has "beaten its bounds") considers that it had originally an elongated lenticular form, and probably thinned away irregularly in every direction from the point of its greatest thickness. In Lincolnshire, its eastern boundary is hidden under superincumbent beds of other formations; and its western boundary, to a very great extent, has been pared away by the denudation which scooped out the great valley of the Witham and the Trent.

It is probable that the Lincolnshire Limestone and the Northampton Sand have no exact analogues elsewhere; but, as the series of these Northamptonshire beds has at its upper limit and lower limit respectively such definite formations as the Oxford Clay and Cornbrash, and the Upper Lias, it may not be impossible approximately to correlate its several members with formations in other parts of the country. I have accordingly drawn up the following Table.

Table showing the Probable Synchronous Relation of the Northamptonshire Beds to Formations in Yorkshire and the South-West of England.

Yorkshire.	Northamptonshire, &c.	S.W. of England.
OXFORD CLAY.	OXFORD CLAY.	OXFORD CLAY.
CORNBRASH.	CORNBRASH.	CORNBRASH.
GREAT OOLITE:—	GREAT OOLITE:—	GREAT OOLITE:—
———	Great Oolite Clay.	Forest Marble. Bradford Clay.
———	Great Oolite Limestone.	Limestones of Great Oolite of Bath, the Cotteswolds, and the Upper Beds at Minchinhampton.
Upper Plant Shale?	Upper Estuarine.	Stonesfield Slate.
INFERIOR OOLITE:—	INFERIOR OOLITE:—	INFERIOR OOLITE:— Zone of *Am. Parkinsoni.*
Grey Limestone of Scarborough.	Lincolnshire Limestone.	Zone of *Am. Humphresianus.*
Lower Plant Shale.	Lower Estuarine. } Northampton Sand.	———
Ferruginous Beds of Glaizedale. The Dogger.	Ferruginous Beds, Upper Portion. } Northampton Sand.	Zone of *Am. Murchisonæ* *.
	Ferruginous Beds, Lower Portion. } Northampton Sand.	Zone of *Am. opalinus*, and the Midford Sand.
UPPER LIAS.	UPPER LIAS.	UPPER LIAS.

The *Great Oolite Clay* is not represented in Yorkshire, but doubtless answers to the Forest Marble and Bradford Clay of the south-west.

The *Great Oolite Limestone*, also, has no representative in Yorkshire, but is probably equivalent to the Great Oolite of the south-west and to the upper beds of Minchinhampton.

The *Upper Estuarine Series*, perhaps, answers to the Upper Plant Shale of Yorkshire, but is more certainly the equivalent of the Stonesfield Slate.

With the *Lincolnshire Limestone*, the series of Inferior Oolite formations comes in. As indicated by the presence of *Am. terebratus*, Phil., it probably is nearly synchronous with the Grey Limestone of

* Dr. Wright, F.R.S.E., F.G.S., in his "Correlation of the Jurassic Rocks," 1869, in a complimentary allusion to my *Stellaster Sharpii*, Wright, describes that fossil has having been discovered in the *Ammonites-Murchisonæ* zone, near Northampton. It was found in the upper portion of the Ironstone section at Duston.

Scarboro', and embraces (as indicated by the occurrence of *Ammonites Murchisonæ*, Sow.) lower beds of the south-west.

The *Lower Estuarine Series* probably tallies with the Lower Plant Shale of Yorkshire, but is not represented in the south-west.

The upper portion of the *Ferruginous Beds* has representatives in the Glaizedale beds and the Dogger of Yorkshire, and in the *Ammonites-Murchisonæ* zone of Cleve Hill, &c.

The lower portion of the *Ferruginous Beds* (as indicated respectively by the presence of *Am. opalinus*, Rein., and of *Am. insignis*, Schubler) is probably nearly equivalent to the *Am.-opalinus* zone of Dr. Wright, and to the Midford sand.

I must not omit to acknowledge the information I have so largely derived from, and which on all occasions has been so freely given by, Mr. Judd, and the great aid which his remarkable Map, sheet 64, has afforded me in revising the rough draft of this Memoir. I must also warmly thank him for the assistance he has rendered me in the preparation of my Map and Diagrams.

My warm thanks are also due to Mr. Etheridge, F.R.S., for the time, great labour, and patience he has bestowed in examining my multitude of fossils, in revising and in many cases correcting my identifications, and in determining those of fossils which were beyond my reach; enabling me to construct the appended Comparative Tables of the organic contents of the several formations.

The preparation of this Memoir has not been unattended with labour upon my part; and the data upon which it is founded have been gathered during many years' acquaintance with, and observations in, the districts to which it refers. If I shall have contributed my quota to a knowledge of the beds I have described and of the geology of the county I have traversed, I shall be satisfied with the result.

The whole of the fossils from the neighbourhood of Northampton which I exhibited on the last occasion were collected by me. A considerable proportion of those which illustrate this my Second Part are also of my collection; some were jointly collected by Mr. Bentley and myself, some by Mr. Bentley alone (notably those from Morcot and Denton), and a few by the late Dr. Porter of Peterboro'.

The ear probably may have wearied in listening to my lengthy and somewhat dry exposition; but the eye, meanwhile, may have rested satisfactorily on the fossils which, fortunately, I have been enabled to exhibit—fossils which are the evidence of the richness of the *fauna* of the periods and of the areas to which I have directed attention.

Exalted personages attend at Court on ceremonial occasions, decorated with the respective stars of their several orders. The distinguished geological entities—the Lincolnshire Limestone and the Northampton Sand—have appeared at the Court of this Society, in like manner decorated with the *Astropecten* and the *Stellaster*, the respective and characteristic "stars"—the *Astrum* and the *Stella*—of those formations.

Fossils from the GREAT OOLITE *Beds of the Northampton and Stamford Districts*.—Table showing which Forms are contained also in the Beds of the* LINCOLNSHIRE LIMESTONE *and the* NORTHAMPTON SAND.

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
LAMELLIBRANCHIATA (*Monomyaria*).				
Avicula				
echinata, *Sow.*	*	*	*	
Münsteri. *Goldf.*	*	*	*	*
Exogyra				
auriformis, *Goldf.*	*			
Gervillia				
crassicosta, *Mor. & Lyc.* (a var.)	*			
Islipensis, *Lycett.*	*	*		
monotis, *Deslong.*	*			
Lima				
cardiiformis, *Sow.* sp.	*	*	*	*
duplicata, *Phil.* sp.	*	*	*	*
impressa, *Mor. & Lyc.*	*	*	*	*
semicircularis, *Goldf.*	...	*	?	
Ostrea				
acuminata, *Sow.*	*			
costata, *Sow.*	*	...	...	*
flabelloides, *Lam.*	*	...	*	*
Sowerbyi, *Mor. & Lyc.*	*	*		
sub-rugulosa, *Mor. & Lyc.*	*	*	...	?
large flat sp. ?	*	*	*	*
Pecten				
annulatus, *Sow.*	*	*		
articulatus, *Schloth.*	*	...	*	*
demissus, *Phil.*	...	*	*	*
Griesbachii, *Lycett.*	*			
lens, *Sow.*	*	*	*	*
—— (or large new sp.) ?	*	*	*	
retiferus (?), *Mor. & Lyc.*	...	*		
—— rigidus, *Sow.*	*			

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O. Stamford.	Linc. Limestone.	Northampton Sand.
Pecten				
Wollastonensis, *Lycett.*	*			
Perna				
foliacea, *Lycett.*	...	*		
(like) mytiloides, *Lam.*	...	*		
quadrata, *Sow.*	*	*	*	
rugosa, *Goldf.*	*	*	*	*
new sp. ?	...	*		
Pinna				
ampla, *Sow.*	*			
cuneata, *Phil.*	*	*	*	*
new sp. ?	...	*		
Placunopsis				
socialis, *Mor. & Lyc.*	*	...	*	
Pteroperna				
costatula, *Deslong.*	*	*	*	*
emarginata, *Mor. & Lyc.*	...	*		
plana, *Mor. & Lyc.*	*	*	*	*
new sp. (finely costated) ?	*			
LAMELLIBRANCHIATA (*Dimyaria*).				
Anatina				
plicatella, *Mor. & Lyc.*	*			
undulata, *Sow.*	*			
Arca				
Eudesii, *Mor. & Lyc.*	...	*		
rugosa, *Mor. & Lyc.*	...	*		
Astarte				
angulata, *Mor. & Lyc.*	...	*		
depressa, *Goldf.*	*	*	*	*
sp. (like elegans, *Sow.*) ?	*			

* *Errata* in the Table published with the First Part of this Memoir have been corrected in this Table, and the names of some Fossils since obtained have been added.

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
Cardium				
Buckmani, *Mor. & Lyc.* ...	*	*	*	*
cognatum, *Phil.*	*	*	*	*
incertum, *Phil.*	*	...	*	
lingulatum, *Lycett*	...	*		
Stricklandi, *Mor. & Lyc.* ...	*	*		
subtrigonum, *Mor. & Lyc.* ...	*	*	*	
Ceromya				
concentrica, *Sow.*	*	*	*	*
plicata, *Ag.* sp.	*			
Symondsii, *Mor. & Lyc.*	*	*		
undulata, *Mor. & Lyc.*	*			
Corbis (Corbicella)				
Bathonica, *Mor. & Lyc.*	*	*		
Cucullæa				
concinna, *Phil.*	*	*		
cucullata, *Goldf.*	*	...	*	*
triangularis, *Phil.*	...	*		
large sp.?	*	*		
Cypricardia				
Bathonica, *d'Orb.*	*	*	*	*
caudata, *Lycett.*	*	*		
nuculiformis, *Römer*	*	*	*	*
rostrata, *Sow.*	*			
Cyprina				
Davidsoni, *Lycett.*	*	*		
depressiuscula, *Mor. & Lyc.*	...	*		
Islipensis, *Lycett.*	*			
Loweana, *Mor. & Lyc.*	*	*	*	
—— var. elongata, *Mor. & Lyc.*	*	*		
trapeziformis, *Römer*	*	...	*	*
Cyrena, sp.?	...	*		
Goniomya				
hemicosta, *Mor. & Lyc.*	*			
Gresslya				
peregrina, *Phil.*	*	*		
Homomya (Myacites)				
crassiuscula, *Mor. & Lyc.* ...	*	*	*	?
unioniformis, *Mor. & Lyc.*	*	*	*	
Vezelayi, *d'Arch.* sp.	*	*	?	?
Isocardia				
nitida, *Phil.*	*			
tenera, *Sow.*	*	*		
new sp.?	*	*		
Limopsis				
oolitica, *d'Arch.*	*	*		
Lithodomus				
inclusus, *Phil.* (very small)	*	...	*	*
Lucina				
Bellona, *d'Orb.*	*	*	*	*

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
Lucina				
crassa, *Sow.*	*			
Macrodon				
Hirsonensis, *d'Arch.* sp. ...	*	*	*	*
—— var. rugosa, *Lycett* ...	*			
Modiola				
cuneata, *Sow.*	*	*	*	*
gibbosa, *Sow.*	*	*	*	*
imbricata, *Sow.*	*	*		
Lonsdalei, *Mor. & Lyc.*	*	*	...	?
Sowerbyana, *d'Orb.*	*	*	*	?
subreniformis, *Mor. & Lyc.*	*	*	...	*
tenuistriata, *Münst.* sp.	*			
Myacites				
Beanii, *Mor. & Lyc.*	*			
calceiformis, *Phil.* sp.	*	*	*	
compressus, *Mor. & Lyc.* ...	*			
decurtata, *Phil.* sp.	*	*	*	
securiformis, *Phil.* sp.	*	*	*	
Terquemea, *Buv.* sp.	*	*		
tumida, *Mor. & Lyc.*	*			
sp.?	*	*		
Mytilus				
asper, *Sow.*	*			
tumidus, *Mor. & Lyc.*	*			
Neæra				
Ibbetsoni, *Morris*	*	*		
Nucula				
Menkei, *Römer*	*			
Waltoni, *Mor. & Lyc.*	*			
Opis				
new sp.?	*	*		
Pholadomya				
acuticosta, *Sow.*	*	*		
deltoidea, *Sow.*	*	*		
Heraulti, *Ag.*	*	*	*	*
lyrata, *Sow.*	*	*	*	
oblita, *Mor. & Lyc.*	*	*		
Sæmanni, *Mor. & Lyc.*	*			
socialis, *Mor. & Lyc.*	*	*		
solitaria, *Mor. & Lyc.*	*	*		
new large sp. with coarse *costæ*	*	*		
new round sp. with irregular *costæ*	*	*		
several undetermined sp. ...	*	*		
Pholas				
oolitica, *Mor. & Lyc.*	*	...	?	
pulchralis, *Bean.*	?			
Quenstedtia				
lævigata, *Mor. & Lyc.*	*	...	...	*
oblita, *Phil.*, sp.	?	...	...	*

Great-Oolite Fossils.	Gt. O., Northampton.	G. O., Stamford.	Linc. Limestone.	Northampton Sand.
Sphæra				
Madridi, *d'Arch.* sp.	*	*		
Tancredia				
angulata, *Lycett*	*	*	*	*
axiniformis, *Phil.* sp.	*	*	*	*
planata, *Mor. & Lyc.*	*	*		*
truncata, *Lycett*	*			
Tellina, sp.?	...	*		
Thracia				
amygdaloides, *Lycett*	*			
curtansata, *Mor. & Lyc.*	*	*		
Trigonia				
costata, *Park.*	*	*	*	*
——, var. pullus, *Mor. & Lyc.*	*	*		
——, var. elongata, *Mor. & Lyc.*	...	*		
Crucis, *Lycett*	*			
Goldfussi, *Ag.*	?			
Moretoni, *Mor. & Lyc.*	*	*		
Unicardium				
impressum, *Mor. & Lyc.*	*	*	*	*
parvulum, *Mor. & Lyc.*	*	*	*	*
varicosum, *Sow.* sp.	*	*		
BRACHIOPODA.				
Rhynchonella				
concinna, *Sow.* sp.	*	*		
Hopkinsi (?), *M'Coy*, sp.	*			
obsoleta, *Sow.* sp.	*	*		
Terebratula				
digona, *Sow.*	*	*		
globata (?), *Sow.* (a var.)?	*			
intermedia, *Sow.*	*	*		
maxillata, *Sow.*	*	*		
obovata, *Sow.*	*	*		
ornithocephala, *Sow.* (or new sp.?)	*	*		
GASTEROPODA.				
Alaria				
armata, *Mor. & Lyc.*	*	...	*	*
trifida, *Phil.* sp.	*	...	*	*
Amberleya				
nodosa, *Mor. & Lyc.*	*	*		
Bulla				
undulata, *Bean*	*			
Cerithium, sp.?	...	*		
Chemnitzia				
Hamptonensis (?), *Mor. & Lyc.*	*			
Delphinula, sp.?	...	*		

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
Dentalium				
sp.?	...	*		
Natica				
formosa, *Mor. & Lyc.*	*	*	*	
globosa, *Römer*	*	*		
grandis, *Goldf.*	*	*	*	
intermedia, *Mor. & Lyc.*	*	*		
Michelini, *d'Arch.*	*	...	*	
neritoidea, *Mor. & Lyc.*	*	...	...	?
texata (?), *Lycett*	*	...	...	
Verneuilii, *d'Arch.*	*			?
(Euspira) canaliculata, *Mor. & Lyc.*	*	*		
—— coronata, *Mor, & Lyc.*	*			
—— pyramidata, *Mor. & Lyc.*	*	*		
—— Sharpei, *Mor. & Lyc.*	*	*		
Nerinæa				
funiculus, *Deslong.*	*			
punctata, *Voltz*	*	...	*	
Stricklandi, *Mor. & Lyc.*	*			
Voltzii, *Deslong*	*	...	*	
sp.?	*	*		
Nerita				
hemisphærica, *Römer*	*	...	...	?
minuta, *Sow.*	...	*		
Phasianella				
acutiuscula, *Mor. & Lyc.*	*			
elegans, *Mor. & Lyc.*	*	...	*	
Pleurotomaria				
armata, *Münst.*	*	...	*	*
scalaris, *Deslong.*	*			
sp.?	...	*		
Trochotoma				
tabulata, *Mor. & Lyc.*	*	*	*	*
Trochus?	*			
CEPHALOPODA.				
Ammonites				
bullatus, *d'Orb.*	...	*		
gracilis, *Buckm.* (large)	*	*		
macrocephalus, *Schloth.*	...	*		
sp.?	*			
small sp.?	*			
large sp.	...	*		
Belemnites				
Bessinus, *d'Orb.*	*	*	*	*
sp. (ungrooved?)	*	*		
Nautilus				
Baberi, *Mor. & Lyc.*	*	*		

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
Nautilus				
hexagonus (?), *Sow.*	...	*		
latidorsatus, *d'Orb.*	*			
subtruncatus, *Mor. & Lyc.*	*	*		
ARTICULATA.				
Serpula				
oblique-striata, *Lycett*	*	*		
socialis, *Goldf.*	*	*	*	*
Annulated Annelide tubes†	*	...	*	*
ECHINODERMATA.				
Acrosalenia				
hemicidaroides, *Wright*	*	*		
pustulata, *Forbes*	*	*		
spinosa, *Ag.*	*	...	...	?
Wiltoni, *Wright*	*	*		
Clypeus				
Mülleri, *Wright*	*	*		
Plottii, *Klein*	*			
Echinobrissus				
clunicularis, *Lhwyd.*	*	*	*	*
Griesbachii, *Wright*	*	*		
sp. (like orbicularis, *Phil.* sp.)?	*			
Woodwardii, *Wright*	*	*		
Hemicidaris				
minor (?), *Ag.*	*			
Holectypus				
depressus, *Leske*	*	*		
Ophiurella				
Griesbachii, *Wright* (Oundle)	...	*		
Pentacrinus				
stem and branch joints	*			
ZOOPHYTA.				
Anabacia				
orbulites, *Lamx.* sp.	*	...	*	
Calamophyllia				
radiata, *Lamx.* sp.	*	...	*	
Cladophyllia				
Babeana, *Edw. & Haime*	*	...	*	
Cyathophora				
tuberosa, *Duncan*	*			
Isastræa				
limitata, *Lamx.*	*	...	*	

Great-Oolite Fossils.	Gt. O., Northampton.	Gt. O., Stamford.	Linc. Limestone.	Northampton Sand.
Isastræa				
gibbosa (?), *Duncan*	*			
POLYZOA.				
sp.?	*	*		
CRUSTACEA.				
Eryma				
sp. (allied to elegans, *Oppel*)?	*	*		
Glyphea				
rostrata, *Phil.* sp.	...	*		
PISCES.				
Hybodus				
dorsalis, *Ag.*—spines	*	*	*	
——, or sp.?—large spines	...	*	*	
Lepidotus				
sp.?—jaw, teeth, and scales	*	*		
Pholidophorus				
Flesheri, *Ag.*	*			
Pycnodus				
Bucklandi, *Ag.*—palate and teeth	*	*	*	
Strophodus				
magnus, *Ag.*—palates	*	*	*	
subreticulatus, *Ag.*—palates.	*	*	*	
REPTILIA.				
Crocodilia				
numerous perfect teeth	*	*	*	
Ichthyosaurus				
sp.?—vertebræ and teeth	*	*		
Plesiosaurus				
sp.?—vertebræ	*			
Teleosaurus				
sp.? (large)—bones, vertebræ, teeth, and dorsal scutes	...	*		
sp.? (small)—jaws, scute, teeth, vertebræ, atlas	*	*	*	
PLANTÆ.				
Carpolithes (fruit)	*	...	...	*
Kaidacarpum				
ooliticum, *Carruth.*	*			
Plants in vertical position	...	*	...	*
Wood	*	*	*	*

† Found also near Banbury.

Fossils from the LINCOLNSHIRE LIMESTONE.—*Table showing which Forms are contained also in the Beds of the* NORTHAMPTON SAND *and of the* GREAT OOLITE *of the Northampton and Stamford Districts.*

Lincolnshire Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
LAMELLIBRANCHIATA (*Monomyaria*).		
Anomia		
smooth sp.?		
(Placunopsis) semi-striata, *Bean.*		
Avicula		
Braamburiensis, *Sow.*	*	
clathrata (?), *Lycett.*		
echinata, *Sow.*	.....	*
Münsteri, *Goldf.*	*	*
sub-costata (?), *Römer.*		
Gervillia		
acuta, *Sow.*	*	
lata, *Phil.*	*	
ornata (?), *Lycett.*		
radians, *Mor. & Lyc.*		
(nearly allied to G. Hartmanni, *Goldf.*)		
Gryphæa		
mima, *Phil.*	*	
Hinnites		
abjectus, *Phil.* sp.	*	
tegulatus, *Mor. & Lyc.*		
velatus, *Goldf.* sp.	*	
Inoceramus		
obliquus, *Mor. & Lyc.*	*	
Lima		
bellula, *Mor. & Lyc.*	*	
cardiiformis, *Sow.* sp.	*	*
duplicata, *Sow.* sp.	*	*
Etheridgii, *Wright.*	*	
gibbosa, *Sow.* sp.		
impressa, *Mor. & Lyc.*	*	*
Luciensis (?), *d'Orb.*	*	
Pontonis, *Lycett*	*	
proboscidea, *Sow.* sp.	*	
punctata, *Sow.* sp.	*	
Rodburgensis, *Lycett, MS.*	*	
semicircularis (?), *Goldf.*	.....	*
large sp. (allied to L. grandis, *Römer*)?	*	
large sp.?	*	
Ostrea		
flabelloides, *Lam.*	*	*
gregaria, *Sow.*	*	
Ostrea		
sulcifera, *Phil.*	*	
large flat sp.?	*	*
Pecten		
aratus, *Waagen.*		
arcuatus, *Sow.*	*	
articulatus, *Schloth.* (a var.?)	*	*
clathratus, *Römer*	*	
demissus, *Phil.*	*	*
——, var. Gingensis, *Quenst.*		
lens, *Sow.*	*	*
——, or new large sp.?	.....	*
personatus, *Goldf.*	*	
vagans (?), *Sow.*		
——, var. peregrinus, *Mor. & Lyc.*		
Perna		
quadrata, *Sow.* sp.	.....	*
rugosa, *Goldf.*	*	*
Pinna		
cancellata, *Bean.*		
cuneata, *Phil.*	*	*
Placunopsis		
ornatus, *Mor. & Lyc.*		
socialis, *Mor. & Lyc.*	.....	*
Plicatula		
tuberculosa, *Mor. & Lyc.*	*	
Pteroperna		
costatula, *Deslong.*	*	*
plana, *Mor. & Lyc.*	*	*
pygmæa, *Mor. & Lyc.*		
Trichites		
nodosus, *Lycett.*		
LAMELLIBRANCHIATA (*Dimyaria*).		
Arca		
æmula, *Phil.*	*	
Prattii, *Mor. & Lyc.*	*	
pulchra, *Sow.*	*	
Astarte		
depressa, *Goldf.*	*	*
elegans, *Sow.*	*	
excavata, *Sow.*	*	
——, var. compressiuscula, *Mor. & Lyc.*		
excentrica, *Mor. & Lyc.*		

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Astarte		
fimbriata, *Walton*, M.S.		
minima, *Phil.*	*	
Pontonis, *Lycett.*		
recondita, *Phil.* sp.		
rhomboidalis, *Phil.* sp. (Hippopodium Luciense, *d'Orb.*)	*	
Wiltoni (?), *Mor. & Lyc.*		
sp.?		
Cardium		
Buckmani, *Mor. & Lyc.*	*	*
cognatum, *Phil.*	*	*
incertum, *Phil.*	......	*
sp. (near to Stricklandi, *Mor. & Lyc.*)?	*	
subtrigonum, *Mor. & Lyc.*	......	*
Ceromya		
Bajociana, *d'Orb.*	*	
concentrica, *Sow.*	*	*
similis, *Lycett.*		
Cucullæa		
cancellata, *Phil.*	*	
cucullata, *Goldf.*	*	*
elongata, *Sow.*	*	
Goldfussii, *Römer.*		
imperialis, *Phil.*	*	
oblonga, *Sow.*	*	
Cypricardia		
Bathonica, *d'Orb.*	*	*
nuculiformis, *Römer*	*	*
Cyprina		
Jurensis, *Goldf.* sp.		
Loweana, *Mor. & Lyc.*	......	*
nuciformis, *Lycett.*		
trapeziformis, *Römer*, sp.	*	*
Cytherea (Cyprina)		
dolabra, *Phil.*		
Goniomya		
literata, *Sow.* sp.		
V-scripta, *Sow.* sp.		
Gresslya, sp.?		
Homomya (Myacites)		
crassiuscula, *Mor. & Lyc.*	?	*
unioniformis, *Mor. & Lyc.*	......	*
Vezelayi (?), *d'Arch.*	?	*
Isocardia		
cordata, *Buckm.*	*	
Lithodomus		
inclusus, *Phil.*	*	*

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N & S.
Lucina		
Bellona, *d'Orb.*	*	*
despecta, *Phil.*	*	
——, var. cardioides, *d'Arch.*	*	
rotundata, *Römer*	*	
Wrightii, *Oppel.*		
——, sp.?		
Macrodon		
Hirsonensis, *d'Arch.*	*	*
Modiola		
Binfieldi, *Mor. & Lyc.*	*	
cuneata, *Sow.* sp.	*	*
—— (a Perna-like variety).		
gibbosa, *Sow.*	*	*
Sowerbyana, *d'Orb.*	*	*
sublævis (?), *Sow.*		
Myacites		
calceiformis, *Phil.* sp.	......	*
decurtata, *Phil.* sp.	......	*
Scarburgensis, *Phil.* sp.		
securiformis, *Phil.* sp.	......	*
Myoconcha		
crassa, *Sow.*	*	
Mytilus		
furcatus, *Goldf.*	*	
lunularis, *Lycett.*		
Opis		
gibbosus, *Lycett.*		
lunulatus, *Sow.* sp.	*	
similis (?), *Deslong.* (or allied sp.?)		
smooth new sp.?		
Pholadomya		
Dewalquea, *Lycett.*		
fidicula, *Sow.*	*	
Heraulti, *Ag.*	*	*
lirata, *Sow.*	......	*
ovalis, *Sow.*	*	
ovulum, *Ag.*		
Zietenii, *Ag.*	*	
large new sp.?		
Pholas? sp.? (oolitica, *Mor & Lyc.*?)	......	*
Tancredia		
angulata, *Lycett*	*	*
axiniformis, *Phil.*	*	*
Tellina, sp.?		
Trigonia		
compta, *Lycett*	*	

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Trigonia		
costata, *Park.*	*	*
——, a minute var.	*	
hemisphærica, *Lycett*	?	
Phillipsii, *Mor. & Lyc.*	*	
sculpta, *Lycett.*		
Sharpiana (?), *Lycett*	*	
spinulosa (?), *Young & Bird.*		
striata, *Miller.*		
V-costata, *Lycett*	*	
Unicardium		
depressum, *Phil.* sp.	*	
impressum, *Mor. & Lyc.*	*	*
parvulum, *Mor. & Lyc.*	*	*
BRACHIOPODA.		
Rhynchonella		
angulata, *Sow.* sp.	*	
Crossii, *Walker.*		
plicatella, *Sow.*		
quadriplicata, *Ziet.*	*	
spinosa, *Schloth.* sp.		
sub-decorata, *Dav.*	*	
sub-tetraëdra, *Dav.*	*	
varians (?), *Schloth.* sp.		
Terebratula		
Buckmani, *Dav.*	*	
fimbria, *Sow.*		
globata, *Sow.*	*	
ovoides, *Sow.*	*	
perovalis, *Sow.*	*	
simplex, *Buckm.*		
sphæroidalis, *Sow.*		
sub-maxillata, *Sow.*	*	
GASTEROPODA.		
Actæonina		
glabra, *Phil.* sp.		
parvula, *Römer*, sp.		
large sp.?		
Alaria		
armata, *Mor. & Lyc.*	*	*
hamulus, *Deslong.* sp.	?	
hamus, *Deslong.* sp.	*	
Phillipsii, *d'Orb.* sp.		
sub-punctata, *Goldf.* sp.		
trifida, *Phil.* sp.	*	*

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Ceritella		
acuta, *Mor. & Lyc.*		
parvula, *Römer*, sp.		
sp. (like Sowerbyi, *Mor. & Lyc.*)?		
Cerithium		
Beanii, *Mor. & Lyc.*		
sp. (like costigerum, *Piette*)?		
gemmatum, *Mor. & Lyc.*	*	
limæforme (?), *Römer.*		
quadricinctum, *Goldf.*		
strangulatum, *d'Arch.*		
Chemnitzia		
vetusta, *Mor. & Lyc.*		
Wetherellii, *Mor. & Lyc.*		
Cylindrites		
acutus, *Sow.* sp.		
brevis, *Mor. & Lyc.*		
bullatus, *Mor. & Lyc.*		
cylindricus, *Lycett.*		
turriculatus, *Lycett.*		
Delphinula		
alta (?), *Mor. & Lyc.*		
sp.? (see 'Phil. G. Y.' i. tab. ix. f. 32).		
(Crossostoma) Prattii, *Mor. & Lyc.*		
Dentalium (?), new sp.?		
Monodonta		
Lyellii (?), *d'Arch.*		
sp. (like Labadyei, *d'Arch.*)?		
Natica		
adducta, *Phil.*	*	
(Euspira) canaliculata, *Mor. & Lyc.*	......	*
formosa, *Mor. & Lyc.*	......	*
grandis, *Goldf.*	......	*
Leckhamptonensis, *Lycett.*		
——, large var. with punctated surface.		
Michelini, *d'Arch.*	......	*
punctura, *Bean*, sp.		
Nerinæa		
cingenda, *Bronn*	*	
Cotteswoldiæ, *Lycett.*		
sp. (like small Eudesii, *Mor. & Lyc.*)?		
sp. (like funiculus, *Deslong.*)?		
gracilis, *Lycett.*		

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Nerinæa		
Jonesii, *Lycett.*		
Oppelii, *Lycett.*		
punctata, *Voltz*	......	*
triplicata, *Bronn*	*	
Voltzii, *Deslong.*	......	*
Onustus ?		
sp. (like Burtonensis, *Lycett*) ?	?	
Patella		
rugosa, *Sow.*	*	
Phasianella		
conica, *Mor. & Lyc.*		
elegans, *Mor. & Lyc.*	......	*
latiuscula, *Mor. & Lyc.*		
parvula, *Mor. & Lyc.*		
Pontonis, *Lycett.*		
tumidula, *Mor. & Lyc.*		
variata (?), *Lycett.*		
Pleurotomaria		
armata, *Münst.*	*	*
sp. (like composita, *Mor. & Lyc.*)?		
sp. (allied to Marcousana, *d'Orb.*)?	*	
ornata, *Defrance.*	*	
sulcata, *Sow.* sp.		
Pterocera		
Bentleyi, *Mor. & Lyc.*		
sp. (allied to ignobilis, *Mor. & Lyc.*) ?		
Pileolus		
plicatus, *Sow.* (an acute var.).		
Rimula		
Blottii, *Deslong*	*	
Rissoina		
obliquata, *Sow.*		
Solarium		
sp. (something like varicosum, *Mor. & Lyc.*) ?		
Trochotoma		
extensa, *Mor. & Lyc.*		
obtusa, *Mor. & Lyc.*	*	
tabulata, *Mor. & Lyc.*	*	*
Trochus		
bijugatus (?), *Quenst.*		
Dunkeri, *Mor. & Lyc.*		
Ibbetsoni, *Mor. & Lyc.*		
Leckenbyi, *Mor. & Lyc.*		
monilitectus, *Phil.*		

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Trochus		
monilitectus, a variety.		
ornatissimus, *d'Orb.*, var. Pontonis, *Morris*	?	
spiratus, *d'Arch.*		
——, a variety.		
squamiger, *Mor. & Lyc.*		
Turbo		
bijugatus (?), *Quenst.*		
depauperatus, *Lycett.*		
gemmatus, *Lycett.*		
sp. (like Gomondei, *Mor. & Lyc.*)?		
ornatus (?), *Quenst.*		
Phillipsii, *Mor. & Lyc.*		
CEPHALOPODA.		
Ammonites		
Blagdeni (?), *Sow.* (young).		
Murchisonæ, *Sow*	*	
sub-radiatus, *Sow.*		
terebratus, *Phil.*		
large sp. (very like sp. found in Ironstone at Duston)	*	
Belemnites		
sp. (like acutus, Miller)?	*	
Bessinus (?), *d'Orb.*	*	*
Blainvillii, *Voltz*	*	
canaliculatus, *Schloth.*	*	
Nautilus		
obesus, *Sow.*	*	
polygonalis, *Sow.*	*	
ARTICULATA.		
Serpula		
convoluta, *Goldf.*	*	
intestinalis, *Phil.*		
plicatilis, *Goldf.*	?	
socialis, *Goldf.*	*	*
sulcata, *Sow.*		
Vermicularia		
noda, *Phil.*		
Annulated Annelide tube (found also near Banbury)	*	*
ECHINODERMATA.		
Acrosalenia		
Lycettii, *Wright*	*	

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Cidaris		
Fowleri, *Wright*	*	
Wrightii, *Desor*	*	
Clypeus		
Michelini, *Wright.*		
Echinobrissus		
clunicularis, *Lhwyd.*	*	*
Galeropygus (Hyboclypus)		
agariciformis, *Forbes*	*	
Holectypus		
hemisphæricus, *Ag.*		
Pseudodiadema		
depressum, *Ag.*		
Pygaster		
semisulcatus, *Phil.*	*	
Stomechinus		
germinans, *Phil.*	*	
Astropecten		
Cotteswoldiæ, var. Stamfordensis, *Wright.*		
Pentacrinus		
sub-sulcatus, *Goldf.* (joints).		
Zoophyta.		
Anabacia		
orbulites, *Lamx.* sp.	......	*
Calamophyllia		
radiata, *Lamx.* sp.	......	*
sp. (like Stokesii, *Edw. & Haime*)?		
Cladophyllia		
Babeana, *Edw. & Haime*	......	*
Isastræa		
limitata, *Lamx.* sp.	......	*
Latimæandra		
Davidsoni, *Edw. & Haime*	*	
Flemingii, *Edw. & Haime.*		
Montlivaltia		
Delabechii, *Edw. & Haime.*		
tenuilamellosa, *Edw. & Haime.*		
Thamnastræa		
concinna, *Goldf.*	*	
——, a very fine variety.		

Lincolnshire-Limestone Fossils.	Northampton Sand.	Great Oolite, N. & S.
Thecosmilia		
gregaria, *M'Coy*	*	
——, a var.		
Genus ?, sp. ?		
Crustacea.		
Pseudophyllia, sp. ?		
Claws—genus ? sp. ?	*	
Pisces.		
Acrodus or Hybodus ? tooth.		
Hybodus		
dorsalis (?), *Ag.*, large spine	......	*
—— (?), small spine	......	*
Pycnodus		
Bucklandi, *Ag.*—teeth	......	*
Strophodus		
magnus, *Ag.*—palates	......	*
sub-reticulatus, *Ag.*—palates	......	*
Reptilia.		
Teleosaurus		
sp. ? sp. ? } teeth.	......	*
Polyzoa.		
Several sp ?	*	
Plantæ.		
Aroides		
Stutterdi, *Carruth.*		
Ferns,		
sp.		
Pecopteris		
polypodioides, *Lindley.*		
Palæozamia		
pectinata, *Brong.*		
Zamia		
sp. ? (small perfect frond).		
Wood	*	*

Fossils from the Ferruginous Beds of the NORTHAMPTON SAND†.—*Table showing which Forms are contained also in the* LINCOLNSHIRE LIMESTONE *and* GREAT OOLITE *Beds of the Northampton and Stamford Districts.*

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
LAMELLIBRANCHIATA (*Monomyaria*).		
Avicula		
Braamburiensis, *Sow.*	*	
sp. (allied to complicata, *Buckm.*)?		
inæquivalvis, *Sow.*		
Münsteri, *Goldf.*	*	*
Gervillia		
acuta, *Sow.*	*	
Hartmanni, *Goldf.* (allied to radians, *Mor. & Lyc.*)	*	
sp. (like Islipensis, *Lycett*)?		
lata, *Phil.*	*	
sp. (like ovata, *Sow.* sp.)?		
pernoides, *Deslong.*		
prælonga (?), *Lycett.*		
(Gastrochæna) tortuosa, *Phil.* sp.		
Gryphæa		
mima, *Phil.*	*	
subloba, *Desh.*		
Hinnites		
abjectus, *Phil.* sp.	*	
velatus, *Goldf.* sp.	*	
Inoceramus		
Fittoni, *Mor. & Lyc.*		
obliquus, *Mor. & Lyc.*	*	
Lima		
sp. (closely allied to antiquata, *Sow.*)?		
bellula, *Mor. & Lyc.*	*	
cardiiformis, *Sow.* sp.	*	*
deltoidea, *Ether.* M.S.		
duplicata, *Sow.* sp.	*	*
Dustonensis, *Ether.* M.S.		
electra, *d'Orb.*		
Etheridgii, *Wright*	*	
impressa, *Mor. & Lyc.*	*	*
interstincta, *Phil.*		
Luciensis (?), *d'Orb.*	*	
pectinoides, *Sow.* sp.		
Pontonis, *Lycett*	*	
proboscidea, *Sow.* sp.	*	
punctata, *Sow.* sp.	*	
Rodburgensis, *Lycett* M.S.	*	
Lima		
rudis, *Sow.* sp.		
Sharpiana, *Ether.* M.S.		
large sp. (allied to L. grandis, *Römer*)?	*	
large sp.?	*	
several new or unidentified forms.		
Ostrea		
costata, *Sow.*		*
cristagalli, *Quenst.*		
flabelloides, *Lam.*	*	*
gregaria, *Sow.*	*	
sub-rugulosa (?), *Mor. & Lyc.*		*
sulcifera, *Phil.*	*	
large flat sp.?	*	*
Pecten		
arcuatus, *Sow.*	*	
articulatus, *Schloth.* (a var.)	*	*
clathratus, *Römer*	*	
demissus, *Phil.*	*	*
lens, *Sow.*	*	*
personatus, *Goldf.*	*	
Perna		
(Inoceramus) quadrata, *Phil.* sp.		
rugosa, *Goldf.*	*	*
Pinna		
ampla, *Sow.* (a var.)		
cuneata, *Phil.*	*	*
Placunopsis		
Jurensis, *Römer.*		
Plicatula		
tuberculosa, *Mor. & Lyc.*	*	
Pteroperna		
costatula, *Deslong.*	*	*
gibbosa, *Lycett.*		
plana, *Mor. & Lyc.*	*	*
LAMELLIBRANCHIATA (*Dimyaria*).		
Arca		
æmula, *Phil.*	*	
minuta, *Sow.*		
Prattii, *Mor. & Lyc.*	*	

† *Errata* in the Table published with the First Part of this Memoir have been corrected in this Table, and the names of some Fossils since obtained have been added.

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
Astarte		
depressa, *Goldf.*	*	*
elegans, *Sow.*	*	
excavata, *Sow.* (a var.)	*	
minima, *Phil.*	*	
rhomboidalis, *Phil.*, sp. (Hippopodium Luciense, *d'Orb.*)	*	
Cardium		
Buckmani, *Mor. & Lyc.*	*	*
cognatum, *Phil.*	*	*
semicostatum, *Lycett.*		
sp. (near to Stricklandi, *Mor. & Lyc.*)?	*	
Ceromya		
Bajociana, *d'Orb.*	*	
concentrica, *Sow.*	*	*
new sp.?		
Corbis (Corbicella)		
sp. (allied to Bathonica, *Mor. & Lyc*?).		
sp. (allied to Lajoyei, *d'Arch.*)?		
Cucullæa		
cancellata, *Phil.*	*	
cucullata, *Goldf.*	*	*
elongata, *Sow.*	*	
imperialis, *Phil.*	*	
oblonga, *Sow.*	*	
ornata, *Phil.*		
large new sp., beautifully cancellated.		
several sps. undetermined.		
Cypricardia		
acutangula, *d'Orb.*		
Bathonica, *d'Orb.*	*	*
nuculiformis, *Römer*, sp.	*	*
Cyprina		
trapeziformis, *Römer*	*	*
Gresslya		
abducta, *Phil.*		
latirostris, *Ag.*		
rostrata, *Ag.*		
Homomya (Myacites)		
crassiuscula (?), *Mor. & Lyc.*	*	*
Vezelayi (?), *d'Arch.* sp.	?	*
sp. (new, allied to gibbosa, *Sow.* sp.)?		
Isocardia		
cordata, *Buckm.*	*	
large "new sp." (*Dr. Lycett*).		
Lithodomus		
inclusus, *Phil.* (very large)	*	*

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
Lucina		
Bellona, *d'Orb.*	*	
despecta, *Phil.*	*	
—— var. cardioides, *d'Arch.*	*	
rotundata, *Römer*, sp.	*	
Macrodon		
Hirsonensis, *d'Arch.* sp.	*	*
Modiola		
Binfieldi (?), *Mor. & Lyc.*	*	
cuneata, *Mor. & Lyc.*	*	*
explanata, *Morris.*		
gibbosa, *Sow.*	*	*
Leckenbyi, *Mor. & Lyc.*		
Lonsdalei (?), *Mor. & Lyc.*	......	*
solenoides, *Mor. & Lyc.* (a new var.).		
Sowerbyana (?), *d'Orb.*	*	*
subreniformis, *Mor. & Lyc.*	......	*
Myacites		
dilatus, *Phil.* sp.		
sp.?		
Myoconcha		
crassa, *Sow.*	*	
Mytilus		
furcatus, *Goldf.*	*	
Opis		
lunulatus, *Sow.* sp.	*	
Pholadomya		
ambigua, *Sow.*		
fidicula, *Sow.*	*	
fidicula? or new sp. (semiacuticosta?).		
Heraulti, *Ag.*	*	*
ovalis (?), *Sow.* (a very large example).		
Zietenii, *Ag.*	*	
large new sp.?		
Quenstedtia		
lævigata, *Mor. & Lyc.*	......	*
oblita, *Phil.* sp.	......	*
Tancredia		
angulata, *Lycett*	*	*
axiniformis, *Phil.* sp.	*	*
planata, *Mor. & Lyc.*	......	*
Trigonia		
angulata, *Sow.*		
compta, *Lycett*	*	
—— (a large var.).		
costata, *Park.*	*	*
—— (a minute var.)?	*	
duplicata, *Sow.*		
hemisphærica (?), *Lycett*	*	

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
Trigonia		
Phillipsii, *Mor. & Lyc.*	*	
Sharpiana, *Lycett*, M.S.	?	
tuberculosa (?), *Lycett*	*	
V-costata, *Lycett*	*	
new sp.?		
Unicardium		
depressum, *Phil.* sp.	*	
gibbosum, *Mor. & Lyc.*		
impressum, *Mor. & Lyc.*	*	*
parvulum, *Mor. & Lyc.*	*	*
BRACHIOPODA.		
Rhynchonella		
angulata, *Sow.* sp.	*	
cynocephala, *Rich.*		
quadriplicata, *Ziet.*	*	
sub-decorata, *Dav.*	*	
tetraëdra, *Sow.*†		
sub-tetraëdra, *Dav.*	*	
variabilis, *Schloth.*		
——, var. bidens, *Phil.* sp.		
——, var. triplicata, *Phil.* sp.		
Terebratula		
Buckmani, *Dav.*	*	
globata, *Sow.*	*	
impressa, *Von Buch.*		
ovoides, *Sow.*	*	
perovalis, *Sow.*	*	
sub-maxillata, *Sow.*	*	
GASTEROPODA.		
Actæon		
Sedgvici, *Phil.* sp.		
Actæonina		
large new sp.?		
Alaria		
armata, *Mor. & Lyc.*	*	*
large sp. (like hamulus, *Mor. & Lyc.*)?		
hamus, *Deslong*	*	
trifida, *Phil.*	*	*
Cerithium		
gemmatum, *Mor. & Lyc.*	*	
Chemnitzia		
Scarburgensis, *Mor. & Lyc.*		
Cirrus		
acutus, *Sow.*		
nodosus, *Sow.*		
Littorina		
punctura, *Bean.*		

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
Natica		
adducta, *Phil.*	*	
neritoidea (?), *Mor. & Lyc.*	......	*
Verneuilii (?), *d'Arch.*	......	*
large spired sp.?		
several undetermined sp.		
Nerinæa		
cingenda, *Bronn*	*	
triplicata, *Bronn*	*	
several small sps.?		
Nerita		
costulata, *Desh.*		
hemisphærica (?), *Römer*	......	*
Onustus?		
sp. (like Burtonensis, *Lyc.*)?	?	
Patella		
inornata, *Mor. & Lyc.*		
nana, *Sow.*		
rugosa, *Sow.*	*	
Pleurotomaria		
Aglaia, *d'Orb.* (a var.)		
armata, *Münst.*	*	*
clathrata, *Goldf.*		
sp. (allied to Marcousana, *d'Orb.*)?	*	
ornata, *Defrance*	*	
pyramidata, *Phil.* sp.		
Rimula		
Blottii, *Deslong.*	*	
Trochotoma		
calix, *Phil.*		
obtusa, *Mor. & Lyc.*	*	
tabulata, *Mor. & Lyc.*	*	*
Trochus		
ornatissimus, *d'Orb.*, var. Pontonis, *Morris* (?)	*	
CEPHALOPODA.		
Ammonites		
bifrons, *Phil.*		
insignis (junior), *Schubler.*		
Murchisonæ, *Sow.*	*	
——, var. corrugatus, *Sow.*		
Niortensis, *d'Orb.*		
opalinus, *Rein.*		
sp. (like solaris, *Phil.*)?		
sp. (unnamed, also found in Inf. Oolite at Yeovil).		
large smooth sp.?	*	
Belemnites		
sp. (like acutus, *Miller*)?	*	

† *Vide* Davidson's Ool. Brach., pl. xviii. fig. 10. It is commonly found in the "Ironstone" of Northamptonshire.

Northampton-Sand Fossils.	L. Limestone.	Gt. Oolite, N. & S.
Belemnites		
Bessinus (?), *d'Orb.*	*	*
Blainvillii, *Voltz*	*	
canaliculatus, *Schloth.*	*	
elongatus, *Miller.*		
phragmacones of large sp.		
Nautilus		
clausus, *d'Orb.*		
obesus, *Sow.*	*	
polygonalis, *Sow.*	*	
sinuatus, *Sow.*		
ARTICULATA.		
Serpula		
convoluta, *Goldf.*	*	
plicatilis (?), *Goldf.*	*	
socialis, *Goldf.*	*	*
Vermicularia		
compressa, *Phil.*		
Annulated Annelide tubes (found also near Banbury)	*	*
ECHINODERMATA.		
Acrosalenia		
Lycettii, *Wright*	*	
spinosa (?), *Ag.*	......	*
Cidaris		
Fowleri, *Wright*	*	
Wrightii, *Desor*	*	
Clypeus		
Hugii, *Ag.*		
Echinobrissus		
clunicularis, *Lhwyd*	*	*
Galeropygus (Hyboclypus) agariciformis, *Forbes*	*	
Hyboclypus		
ovalis, *Wright.*		
Pygaster		
semisulcatus, *Phil.*	*	
Stomechinus		
germinans, *Phil.*	*	
Stellaster		
Sharpii, *Wright.*		
Pentacrinus		
stem and branch joints.		
ZOOPHYTA.		
Isastræa		
explanulata, *M'Coy.*		
Richardsoni, *Edw. & Haime.*	*	
Latimæandra		
Davidsoni, *Edw. & Haime.*		
Montlivaltia		
Wrightii, *Edw. & Haime.*		
Stylina		
solida (?), *M'Coy.*		
Thamnastræa		
concinna, *Goldf.*	*	
Thecosmilia		
gregaria, *M'Coy*	*	
Wrightii, *Duncan.*		
Several undetermined genera and sp.?		
AMORPHOZOA.		
Spongiæ, sp.?		
POLYZOA.		
several sp.?	*	
CRUSTACEA.		
claws, &c., sp.?	*	
REPTILIA.		
Megalosaurus—tooth.		
Teleosaurus, undescribed sp.? } dorsal scute.		
PLANTÆ.		
Impressions—		
bracts of cones?		
flag-like leaves, with seeds.		
leaf-shape pinnule of fern-frond, showing venation and sori.		
Carpolithes (fruit)	......	*
Seeds.		
Wood	*	*

Approximate Analysis of the Synchronous Distribution of Fossils.

The foregoing Lists give the following results:—

Number of Great-Oolite forms	230
„ „ Lincolnshire-Limestone forms	315
„ „ Northampton-Sand forms	250
Total	795

Of these—

135 are common to the Northampton Sand and the Lincolnshire Limestone.

70 to the Lincolnshire Limestone and Great Oolite.

46 to the Great Oolite and Northampton Sand.

43 to all three formations.

If, from the number of forms common to the Northampton Sand ahd the Lincolnshire Limestone, and from the number common to the Lincolnshire Limestone and the Great Oolite, respectively, be deducted the number of forms common to all three formations (as having no significance in determining their comparative affinity), there will remain:—

92 forms common only to the Northampton Sand and the Lincolnshire Limestone.

27 forms common only to the Lincolnshire Limestone and the Great Oolite.

Many fossils of the Lincolnshire Limestone and Northampton Sand have yet to be identified and described, which ultimately will considerably swell the foregoing numbers as regards those formations.

EXPLANATION OF PLATES IX. AND X.

Plate IX.

Map of the author's route and of the southern portion of the Lincolnshire Limestone. * * Points of thinning-out of the Lincolnshire Limestone. For section see Pl. X. fig. 2.

Plate X.

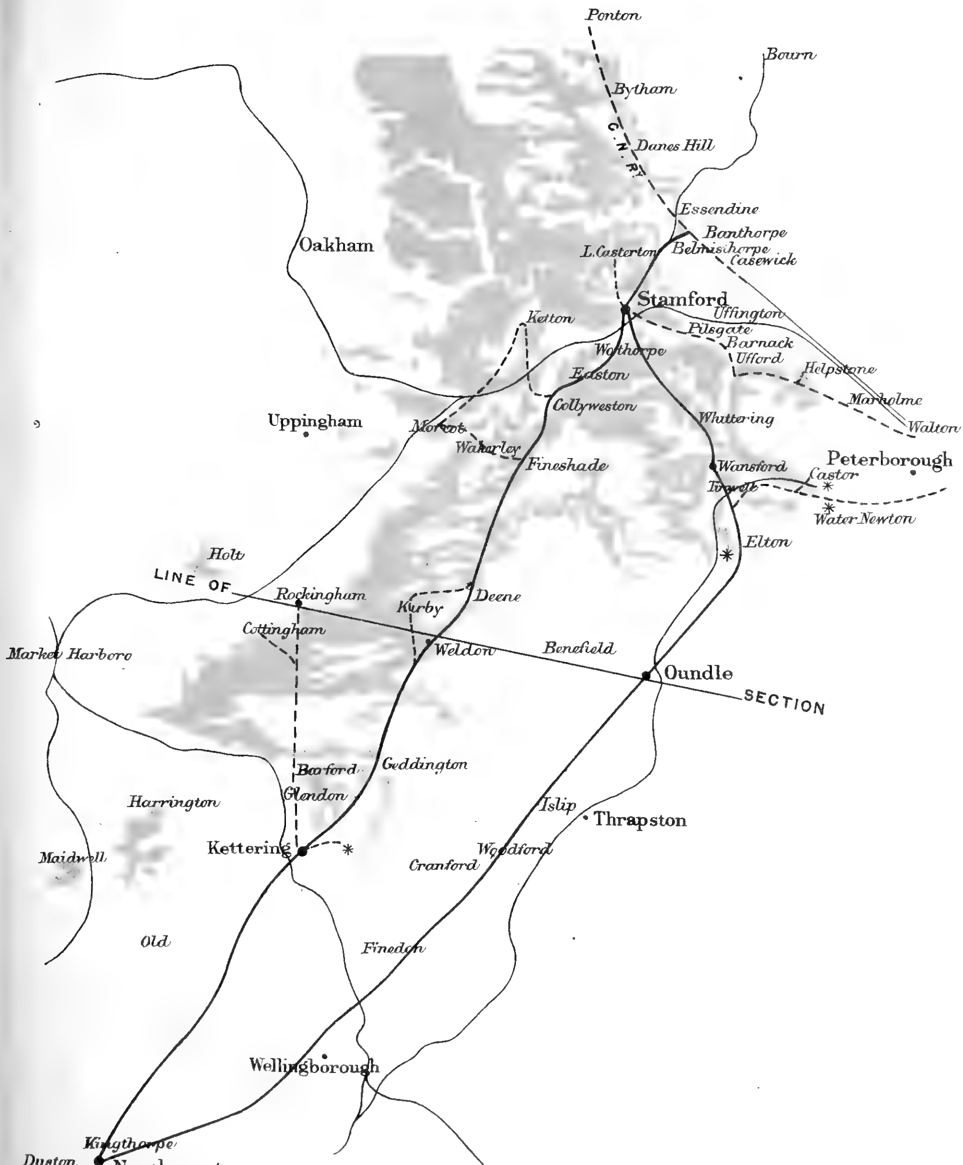
Fig. 1. Diagrammatic section across the Welland Valley at Stamford.

Fig. 2. Generalized section from the valley of the Welland to that of the Nene, illustrating the thinning-out of the Lincolnshire Limestone.

Discussion.

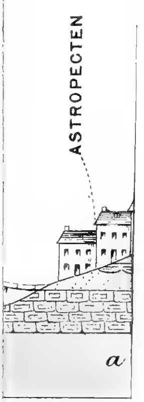
Mr. Etheridge expressed his obligation to the author for his paper, and for the remarkable collection of fossils he had exhibited. The ground over which he had worked was one the features of which had required a great amount of well-directed labour to decipher. He considered, however, that Mr. Sharp and Mr. Judd had settled the question of the sequence of these rocks, and their relation to the Oolitic beds of Yorkshire to the north, and Gloucestershire to the west. The importance of the determination of the position of a bed of such commercial value as the Northampton Sand could hardly be overestimated; and it was to Mr. Judd and to the author that this

MAP OF ROUTE AND OF SOUTHERN PORTION OF AREA OF THE LINCOLNSHIRE LIMESTONE.



Mintern Brosᵉ Lith.

HE WELLA



ton Slate

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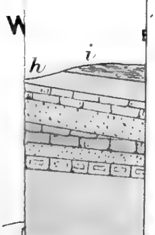
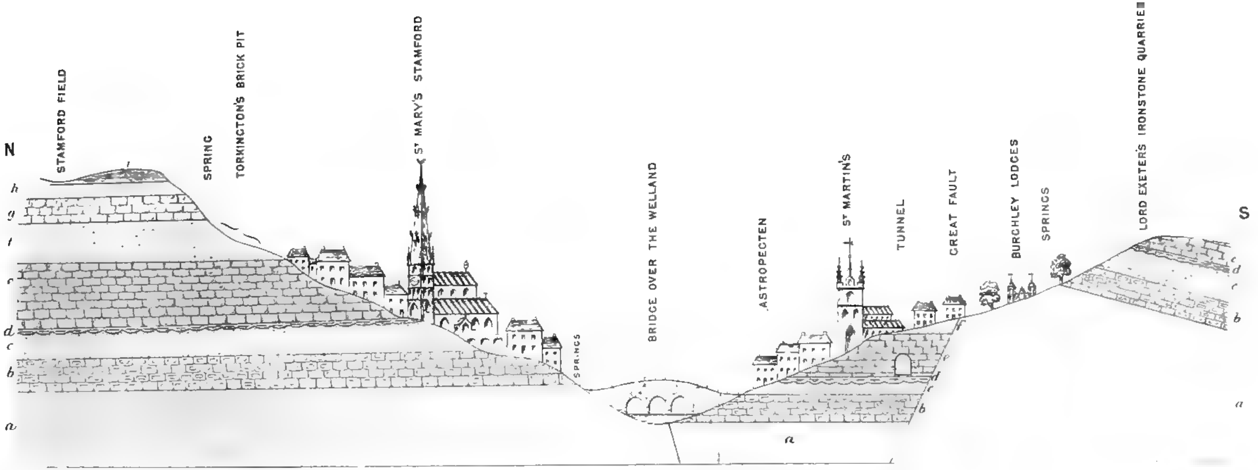


shire Lime
mpton Sand
Lias Clay
of thinning

Fig. 1.

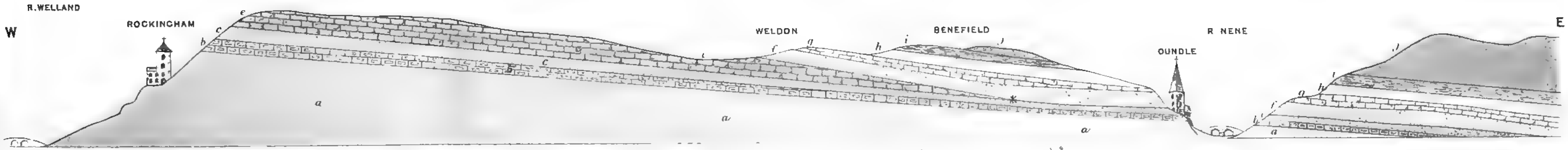
DIAGRAM OF SECTION ACROSS THE WELLAND VALLEY AT STAMFORD



d Collyweston Slate

Fig. 2.

GENERALIZED SECTION FROM THE VALLEY OF THE WELLAND TO THAT OF THE NENE, ILLUSTRATING THE THINNING OUT OF THE LINCOLNSHIRE LIMESTONE



j Oxford Clay
i Cornbrash
h Great Oolite Clay
g " " Limestone
f " " Upper Estuarine
e Lincolnshire Limestone
c —d Northampton Sand, Lower Estuarine
b " " Ferruginous Beds
Inf. Oolite
a Upper Lias Clay
* Point of thinning out of Lincolnshire Limestone

Mintern Bros lith

determination was due. It had, moreover, been attained under very adverse circumstances; for at the time when the survey of the district had been undertaken, the Lincolnshire Limestone had not been recognized; and even Prof. Morris had at first failed to see that this bed intervened between the Northampton Sand and the Great Oolite. It was mainly due to the extensive collection formed by Mr. Sharp that the key to the existence of this important bed and to the geological history of the whole district during the Mesozoic period was discovered. The mapping of the country was not to be effected by studying merely its lithological characters, but was mainly dependent on a knowledge of the palæontological features of each of the successive beds. Mr. Etheridge pointed out the close correspondence between the position of the Northampton beds and those of Yorkshire, with the exception of the absence of the Great Oolite in the latter area. Though the Stonesfield slates and the Collyweston beds were so similar in lithological character that even the most experienced might take the one for the other; yet, when the organic contents came to be examined, the difference became evident; and in Mr. Sharp's paper stratigraphical evidence had been brought to corroborate the palæontological, and to show conclusively the difference in the horizon of the two beds.

Mr. Judd could not overestimate the value of Mr. Sharp's labours, extended, as they had been, over nearly a whole lifetime. They afforded another instance of the great value of local inquiries in geology. It was becoming more and more evident that the sequence of beds which held good for one place required some modification in another, and that in each case there was a more or less distinct local series—showing that in no one locality was the sequence absolutely perfect, as indeed had been already pointed out by Mr. Darwin.

Mr. Charlesworth remarked on a specimen of the teeth of the genus *Lepidotus* exhibited, consisting of cylindrical columns surmounted by a conical crown, which struck him os one of unusual interest in the magnificent collection displayed. He commented on the value of such local collections for palæontological purposes, and on the necessity of their being formed if the progress of geology was to be furthered.

Prof. Duncan also was highly impressed with the value of Mr. Sharp's collection. He remarked on two specimens of Madreporaria, one of which, *Thamnastræa concinna*, presented a series of ridges significant of intermittent growth. The other form presented a strange relic of palæozoic coral forms, being intersected by tabulæ like those of ancient times. It afforded an instance of a tabulate Actinozoon, in opposition to the opinion of Agassiz that the Tabulata belonged to the Hydrozoa. Both species grew on narrow bases; and though not reef-corals, were forms such as were to be found in the neighbourhood of reefs. Taken in conjunction with the Saurian remains, he thought they were symptomatic of shallow sea conditions, such as those existing between the continent of America and the West-Indian Islands.

Mr. H. Woodward contrasted the collections formerly exhibited

to the Society with that now shown, inasmuch as in former times the same amount of regard had not been paid to the stratigraphical position of the specimens, and their value was in consequence almost destroyed.

Mr. Sharp, in reply, mentioned that some portion of his collection had been formed by Mr. Bentley, and not by himself, and that therefore he could not claim the credit of the whole. He was gratified to find that there was so little disagreement with his conclusions.

The Chairman (Mr. Warington W. Smyth), in conclusion, expressed his satisfaction at the fact that, notwithstanding the existence of the Geological Survey, there was still room left for individual discovery and research, which in this instance had served to rectify what might have been erroneous views on the part of the Survey.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY.

From October 1st to December 31st, 1872.

I. TRANSACTIONS AND JOURNALS.

Presented by the respective Societies and Editors.

American Journal of Science and Arts. Series 3. Vol. iv. Nos. 22 & 23. October and November 1872.

O. C. Marsh.—Notice of some New Tertiary and post-Tertiary Birds, 256.
E. W. Hilgard.—On some points in the Geology of the South-west, 265.
F. B. Meek.—Descriptions of a few new species and one new genus of Silurian Fossils from Ohio, 274.
O. C. Marsh.—Preliminary Description of New Tertiary Reptiles, 298.
J. Le Conte.—A Theory of the Formation of the great Features of the Earth's Surface, 345.
J. D. Dana.—On the Quartzite, Limestone, and associated rocks of the vicinity of Great Barrington, Mass., 362.
E. Billings.—Rejoinder to Prof. Hall's reply to a "Note on a question of Priority," 399.

Amsterdam. Jaarboek van het mijnwezen in Nederlandsch Oost-Indië. Part i. 1872. *Presented by the Netherlands Government.*

Athenæum (Journal). Part 538, Oct. 1872, and Part 539, Nov. 1872, also Nos. 2345–2355.

Belfast Naturalists' Field-Club. Ninth Annual Report. 1871–72.

W. Gray.—An Inquiry into the Possibility and Probability of the occurrence of Coal in the neighbourhood of Belfast, 26.
J. Wright.—The Geology of Cultra, co. Down, 33.
W. M'Ilwaine.—The Stone Period, 40.

Berlin. Monatsbericht der königlich-preussischen Akademie der Wissenschaften. May to August 1872.

Ewald.—Ueber die Ausbildungsweise der oberen Juraformation im Magdeburgischen, 484.
Vom Rath.—Ueber das Krystallsystem des Leucits, 623.

——. Zeitschrift der deutschen geologischen Gesellschaft. Band xxiv. Heft 2. February, March, and April 1872.

A. Sadebeck.—Hemiëdrie der scheinbar holoëdrischen Formen der Blende und des Kupferkieses, 179.
J. Lemberg.—Ueber die Contactbildungen bei Predazzo, 187.
H. Laspeyres.—Geognostische Mittheilungen aus der Provinz Sachsen, 265.
H. Trautschold.—Das Gouvernement Moskau, 361.
Reiss.—Mittheilungen über eine Reise in Südamerika, 377.
M. Bauer.—Mineralogische Mittheilungen, 385.
F. Pfaff.—Beiträge zur Experimentalgeologie, 401.
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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

February 26, 1873.

James Henry Johnson, Esq., Strangeways, near Wigan; Henry Louis Philipps, Esq., 19 Warrington Crescent, Maida Vale, N.W.; and William Henry Holloway, Esq., of the Geological Survey of England and Wales, 28 Jermyn Street, S.W., were elected Fellows of the Society.

The following communications were read:—

1. *On the* Jurassic Rocks *of* Skye *and* Raasay. By James Bryce, M.A., LL.D., F.G.S. *With a Palæontological Appendix,* by Ralph Tate, Esq., F.G.S., A.L.S.

[Plates XI. & XII.]

Introduction.—The portion of Skye which is the subject of the present paper has received only a few passing notices since 1819, when Dr. Macculloch's 'Account of the Western Islands,' was published. Raasay, as being much less accessible, has been even more casually noticed; and Dr. Macculloch's account of its geological structure is the only one which we possess. This distinguished geologist, who did so much admirable work in Scotland, was the first to show that the fossiliferous strata of Skye, Raasay, and the islands adjoining were of the age of the English Lias and Oolites. In 1827 Sir R. Murchison determined, from the existence in them of

three or four critical fossils, that the Lower and Middle Oolite were represented by beds to the north of Portree harbour, and that the beds about the mouth of Loch Sligachan and at Broadford were the lowest of the fossiliferous series. In 1851 Prof. Edward Forbes ascertained that certain strata at Loch Staffin, supposed by Sir R. Murchison, from the examination of a few imperfect fossils, to be of the age of the Wealden, really belonged to the upper part of the Middle Oolite. No addition worthy of record was made to our knowledge of these beds in Skye till 1858, when a paper appeared from the pen of Prof. Geikie (Quart. Journ. Geol. Soc. vol. xiv. p. 1), on the Lias basin south of the Red Mountains in Skye, and crossing the peninsula from Broadford Bay and Lussay to Loch Slapin. He showed that in this basin, which may be said to include as outliers the Scalpa and Pabba beds, there existed the Lower Lias and the lower portion of the Middle Lias—a conclusion fully borne out by the evidence derived from 30 species of fossils collected by him, when carefully correlated with those of England by Dr. Wright of Cheltenham, well known for his great skill in this branch of palæontology. The work thus far done indicated clearly the line of inquiry to be pursued by observers who should follow. It remained to determine whether the Middle Lias had a greater development in the northward range of the beds, whether the Upper Lias existed, what were the extent and relations of the Oolitic beds, and to procure a full suite of fossils in order more surely to fix the various "horizons" and to correlate the whole series in a satisfactory manner with the like beds in England and in other countries.

With these objects mainly in view, I visited Skye for the first time in June 1869; and during that visit, and others in the three succeeding years, I made the observations and collected the fossils which I have now the honour to lay before the Society. The specific determination of the fossils has been made by Mr. Ralph Tate, F.G.S., well known to geologists for his accurate acquaintance with the fauna of the Jurassic beds; and a Report from him regarding them is appended to the present paper. The fossils were submitted to and named by him from time to time; and before drawing up the Report he had an opportunity of inspecting many of the sections, both in Skye and Raasay, while accompanying me during part of my last visit, in June 1872; so that he has been enabled to form a more accurate estimate of the relations between the position of the fossils in these beds and that which they occupy in the more perfectly developed series in the magnificent cliffs and extensive moors of East Yorkshire, with which he has been long familiar, and in which the fossils are much more abundant and in far better preservation.

Range of the Beds.—Separated from the valley of Strath by the three great ridges of the syenite mountains, the calcareous strata emerge again near Sconser, at the entrance of Loch Sligachan; they rise to the height of several hundred feet on the north-west front of the syenitic mountain Glamaig. Two miles from the head of the loch they become overlain by the igneous rocks which form the floor

of Glen Sligachan, and appear no more to the southward. On the western side of the loch, however, Jurassic beds emerge, at a low level, from under the sea-line, rising towards the north-east, and dipping westerly at 10° to 15°. They form but a narrow band, and are covered by the ordinary trap rock of the country, which forms the long and lofty ridge bounding Loch Sligachan on the west. The loch in fact seems to be in a line of fault, which has brought up the beds from the sea-level on the north-west to a height of about 500 feet on the south-east; and the loch thus seems to have been eroded upon these Secondary strata. The Oolitic beds continue their course along the grassy plateau on which the Clachan of Balmeanach is situated, until they are lost under the basaltic cliff which begins to occupy the sea-line opposite the west end of the small peninsula of Ardvornish; seaward they are cut off by a band of whitish-grey felsite (felspar porphyry), which forms the peninsula, appears again at the landing-place in Raasay, and figures so largely in the geology of that island. I was unable to determine whether this disappearance is due to a fault or one of the many undulations to be seen on this coast (see Pl. XI. fig. 5).

The low basaltic cliff now occupies the coast-line for two or three miles, till we reach within a quarter of a mile of the small fishing-harbour of Camus-Inivaig, where a small patch of the sandstone again shows itself, to be again depressed till we pass the harbour and the shore begins to trend eastward. Here the strata emerge from the sea-line in beds successively lower as we advance east, north-east, and north along the shore, and, rising rapidly northwards, attain under the highest part of the basaltic façades of Inivaig a thickness of about 800 feet. Here the beds attain a great development, the lowest fossiliferous stratum in this northern area now rising high in the cliffs. Round both sides of Portree harbour the beds are again depressed below sea-level, or wholly cut off by the overlying trap, continuous from this point along the back of the cliffs as far as Camus-Inivaig. On the north-east side of the harbour the beds again rise from under the basaltic sheets of the plateau, and exhibit their inclined edges along the hill-side for a short distance, are again cut off by the advance of the trap rock, and then rise again to attain an even greater development than in the southern precipices, especially as regards the upper beds, in the steep, almost impassable, grassy slopes under the vast basaltic façades of Torvaig, 1280 feet high. At the back of these precipices there is a considerable area denuded of the basaltic cover, in which the upper beds are exposed around the two small lakes, Fada and Lea-than (long and broad lakes), and in the gullies which descend towards them from the eastern ridge (see Map and Sections, Pl. XI.). Thence the strata sweep round by the great waterfall and unite with the beds upon the shore, to the north of the Holm Island. Hence the trap rock which forms the grand precipices of the Storr, descending by successive terraced slopes, comes close upon the shore, leaving but a narrow band of the calcareous beds, which front the sea in low cliffs hence till the headland of Ru-na-Bhrarin is approached. Here trap

rocks occupy the shore, and the calcareous beds retire inland and form a band of some breadth in the beds and banks of the streams to a considerable distance inland, the trap covering having been swept away at these parts, but still existing on the intervening low ridges between the streams. In this tract several faults occur, of which the most striking are:—one on the Leathan-alt, near the hamlet of Half-burn, attended with great disruption and a downthrow towards the sea-shore; and another at the waterfall of the Loch Me-alt (Miagh-alt), where the calcareous beds are cut off, and the overlying trap occupies the whole of the lofty cliff down to the sea-line. The over-lying trap of the cliffs west of Loch Me-alt now advances inland and connects on to that of the high moors southwards to the base of the great central range of the peninsula, which extends from near Portree to beyond the Quiraing. As the ground lowers again towards Loch Staffin, the calcareous beds emerge, and have a considerable range round the head of the bay, and westwards by the north base of the Quiraing Mountain. Now they are seen in the coast section, and again they are cut off by the intrusive trap which takes their place in the section. This arrangement is continued round the north point of the peninsula, by Aird Point and Ru-Hunish, to Duntulm Castle, where a remarkable change is produced upon them by the trap. By the roadside east of the castle the beds emerge unaltered, and form a narrow band for some distance in the coast-line. They are again seen south-east of this point on the western shore of the peninsula, and on the banks of Mugstok lake drained fifty years ago. Their last appearance on the coast of Trotternish is at Uig Bay. Here, on turning the headland of Ru-Idrigal, conspicuous from most parts of the western peninsulas of Skye, we come again suddenly on beds which range round the head of the bay, along the narrow band of fertile land between the sea-line and the steep front of the high ridge which shuts in on three sides this secluded inlet, giving it a winter temperature differing little from that of the south coast of Devon.

The western peninsula presents the same beds in a few places where the level of the sea is reached, or a level very little raised above it, as at the head of Loch-bay in Vaternish, on an island at its entrance, and on the low sea cliff at Vaterstein, west of Dunvegan.—This low normal position of the beds suggested to Dr. Macculloch the idea that the whole island has a substratum of these rocks, and that the few elevated positions in which we now find them are due to local elevation. He was the first to suggest the former connexion of all his "trap islands," and to conceive the idea of a Liassic sea embracing all of them, and the north of Ireland also, whose floor consisted of these beds, afterwards broken through and overlain by vast sheets of lava.

Succession of the Beds.—In order to obtain a good base for future operations, I went with some care over the district described by Prof. Geikie, and I can bear testimony to the faithfulness, clearness, and accuracy of his paper. The conclusions are so satisfactorily made out that it is only necessary, in consequence of the discovery

of the fossils now described, to give a little more precision to the conclusions which he and Dr. Wright have arrived at in regard to the age of the beds, by simply noting that the Broadford strata represent the main mass of the Lower Lias, and contain such Ammonites as characterize the zone of *Ammonites Bucklandi*—the coralliferous beds at Lussay being on that of *Ammonites angulatus*, the lower portion of the Lower Lias. The authors are undoubtedly correct in assigning the Pabba shales to the horizon of *Ammonites Jamesoni*—that is, the lower portion of the Middle Lias. Scalpa was not examined; and no additional evidence can be brought to bear on the conclusion of the paper (founded on three fossils only, of which not one was an Ammonite), that these beds are the equivalents of the Marlstone and represent the *Ammonites-margaritatus* and *Ammonites-spinatus* beds of the Middle Lias. Following the beds in their further development northwards, I found the portions of the Lias formation, higher in the series, fully represented and distinctly characterized by the fossils peculiar to the beds in other districts. This will be best shown by a few detailed sections along the line on which the beds successively rise, beginning with those at Sligachan, the southern limit of the area embraced in the present paper.

Sections of the Beds.—The calcareous strata already referred to as emerging at Sconser are those of the Lower Lias. They occupy the south-east shore of the loch from the sea-line to the height of about 500 feet, where they rise against the syenite of Glamaig. The upper beds, towards the road and sea-level, dip at an angle of about 40°, the lower beds, next the syenite, at 70°, the higher inclination being plainly due to the proximity of the erupted rock. In the northern part of the area the dip is N.W.; but southwards, as the overlying trap is approached, it is more towards the W. The ground is so tossed and encumbered with detritus, that a true section of the beds cannot be obtained. It can only be stated in a general way that the lower beds consist of altered shales, coarse sandstones, and conglomerates, and the upper of indurated dark and grey limestones and dark-coloured shales. The following are the fossils contained in these upper beds:—*Gryphæa arcuata, Belemnites infundibulum, Rhynchonella ammonitica, Pecten textorius, Lima pectinoides, Avicula novemcostæ.* These seem to show, by comparison with the Broadford and Hallaig beds, that we are here on the horizon of *Ammonites Bucklandi*. Calculating from the distance along the outcrop and the average dip, the thickness of the beds may be safely reckoned at 800 feet, which is very much greater than that of the Lower Lias, or indeed any member of the series within the whole of this northern area. There being so little breadth of ground intervening between the base of Ben Glamaig and the sea, the Middle and Upper Lias could not be expected to come on here; but both probably exist below the waters of the loch; and it is to their erosion that reference has been already made. The beds referred to in the same passage as appearing on the W. shore of the loch at a low level, are a whitish and a dark-coloured sandstone, whose range has been already traced, but whose true

relations are not revealed to us till we find them at Camus-Inivaig, superimposed as Inferior Oolite on the top of the Upper Lias. This is sufficient evidence to justify the view of the upthrow and erosion above suggested*.

The first of our Sections is taken close to Tanna Point on the south-east side of Portree harbour, where, as already noticed, the series rises to a great height under the basaltic precipices of Inivaig mountain, which reaches the height of 1346 feet. There are many faults and slips upon these impassable slopes; and hence it was necessary to stand out a little in a boat, and select a spot free from both causes of error, and where it was possible to climb to a considerable height, in order to make sure of the true sequence.

After this reconnaissance the boat was pushed into a long and narrow cleft, made by the wearing away of a large whin-dyke, whose course could be traced far up into the overlying trap; and the following clear section was obtained, including the Middle and Upper Lias and base of the Inferior Oolite.

Section I. (order descending).

Upper Lias, with the characteristic *Ammonites communis* throughout.

	ft.	in.
1. Argillaceous dark blue limestone	0	4
2. Black shales	3	0
3. Line of nodular blue limestone, showing oolitic structure in part and with pyrites; *Ammonites communis* and *A. falcifer* abundant and of large size	0	3
4. Stiff black shales, slightly micaceous, with *Ammonites falcifer*, *A. heterophyllus*, *Inoceramus dubius*, &c.	8	0
5. Brown crystalline limestone	0	6
6. Black friable shale	1	6
7. Compact blue argillaceous limestone	1	3
8. Finely laminated black shale, with *Ammonites bifrons*	0	9
Total thickness	15	7

Other fossils furnished by this series will be found in the lists appended.

Underneath these beds come about 60 feet (estimated) of the Middle Lias, as follows, *in descending order*.

Middle Lias.

a. Yellow calciferous sandstone, the upper part more calcareous, and approximating to the dark blue limestone, at the base of the Upper Lias; *Ammonites-spinatus* beds.

b. Bluish micaceous sandstone, thinly bedded with lines of large blue calcareous nodules and septaria, with *Ammonites margaritatus*, *Pecten æquivalvis*, *P. liasinus*, *Limea acuticosta*, *Pentacrinus amalthei*, &c. (See lists.)

c. Hard micaceous sandy and calcareous shales, with rows of spherical calcareous nodules. *Pecten æquivalvis* very large, *Pholadomya ambigua*, *Plicatula spinosa*, &c. This bed descends to the sea-line along the whole shore, from Portree harbour to Camus-Inivaig; and there are no means of estimating the total thickness.

* Not having made myself up on the literature of the subject before my first visit to Skye, as it is not always ready to one's hand, I had satisfied myself that the beds on the east side of Sligachan were Lower Lias, and that the sand-rock on the west side was a continuation of that of Camus-Inivaig, before I found

The usual character of the top bed of the Middle Lias is that of a hard thick-bedded calcareous sandstone of a yellow or yellowish brown colour, hard and tough, with occasional beds of crystalline limestone, resembling a marble of the Carboniferous formation. The external surface is often honeycombed, the holes being so large that a man's fist can be thrust into them; there are also rows of large lenticular reddish masses consisting of a fine-grained limestone, extremely hard and tough, and often showing a concentric structure. The beds are also ridged with harder portions, whose cement is iron or lime, and which project, as being more enduring. For the other fossils see the lists annexed.

The Oolite Sandstones are seen in this section to rest upon the Upper Lias; but the bed in contact can be reached only in this place. The following section is taken further west, and is accessible from the foregoing only by water. A cleft in the steep hill-slope ascends from the west side of a huge fallen and overhanging mass of Middle Lias to the basaltic plateau at the top of the cliffs. The Middle and Upper Lias form the lower part of the section, with the same lithological characters as those just described, and yielding similar fossils. Resting directly on the Upper Lias, the Inferior Oolite here forms three very distinct beds. The beds all dip nearly west at small angles, 7° to 12°.

Section II.

The lower portion, which may be called subdivision A, is about 100 feet thick, consists of dark grey sandstones, alternating with micaceous, argillaceous, and sandy beds, and, near the top, shaly sands extensively stained with carbon, and containing pieces of jet; a blue calciferous sandstone terminates the series above. The bottom bed has the characteristic fossils, *Ammonites Murchisonæ, Pecten Dewalquei*, and *Lucina Wrightii*. Belemnites of several species occur throughout, more especially in the sandy beds. The fossils are most abundant in the lowest beds (see lists).

Subdivision B. (Upper Series).—This is a yellow or white sand-rock, very easily broken under the hammer, and then into powder under the hand; it is about 50 feet thick, and contains many plant-remains too imperfect to be determined, and also occasionally small pieces of jet. The beds of contact with A are of a grey colour.

Subdivision C.—This is on the top; is from 1 to 3 feet thick, and consists mainly of a shaly crystalline limestone, with sandy shale partings; *Avicula costata* and *Rhynchonella concinna* occur.

These beds are those which Sir R. Murchison conjectured to be the representatives of the Cornbrash and Forest Marble; the beds, indeed, fall naturally into two lithological divisions, which are closely analogous to those of the Yorkshire coast, near the base of the Oolitic series: our third division C is here insignificant; but inside Portree

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that Sir R. Murchison had made the observations already quoted, or that Dr. Macculloch had traced the sand-rock into continuity with the beds at Camus-Inivaig. Dr. Macculloch is often vague and unsatisfactory, but very seldom indeed does he commit himself to a statement which we have found incorrect.

Harbour the limestones are 40 feet thick. The whole series has about the same dip and inclination as in last section. *Ammonites Murchisonæ* is abundant in the sandy shales near the top of the series, but it occurs also throughout. Division C is characterized by *Avicula costata*, *Rhynchonella concinna*, *Terebratula lagenalis*, and *Ostrea Sowerbii*.

Section III.

Another section of considerable interest in this part of the series can be easily visited from Portree, and is approached by land without difficulty. It is to be seen five miles south of Portree on the east side of Camus-Inivaig bay, where the fossiliferous beds emerge from under the sea-line. The section is as under, in ascending order from the sea-level.

Lias and Oolite.

1. Middle Lias; a yellow calciferous sandstone, with sandy shales in the upper part of the series; descends under the sea-line.
2. Upper Lias shales about 10 feet; without limestone.
3. Sandstone of the Lower Oolite without strong lines of stratification; in the lower part grey flaggy sandstones, on the top yellow sandstones with irregular oblique bedding.
4. A sheet of basaltic rock, chiefly compact dolerite, about 60 feet thick. It strikes the sea-line a little to the west of the section, forming the tide-way, and gradually ascends eastwards; finally it thins much in this direction, and cutting through the beds No. 5 above, runs on to join the overlying trap.
5. Flaggy sandstone of the Oolite; upper part of Lower Oolite, with oblique irregular bedding, about 40 feet.
6. Rocks of the basaltic plateau, declining towards the head of Camus-Inivaig, extending thence to Portree and Sligachan, and westward over the interior moorlands. The dips here are a little to S. of W., at angles of 8° to 12°.

The lines of contact of bed No. 4 show remarkable changes in the sedimentary rock. Where the Oolitic sandstone No. 5 is argillaceous, it is converted by contact with the underlying trap into a dark-blue, almost black Lydian stone, banded with parallel grey streaks: when siliceous, the rock is changed into a hard dark-grey sandstone, almost a quartzite. Beds of coal, interstratified with layers of sand, the joint thickness being about 12 or 15 inches, occur at intervals along the whole line of contact. The coal is of an earthy grey and crumbling on the outer surface; but within it approaches to jet in hardness and lustre. The changes indicate the injection of the trappean rock after the deposition of the Oolitic beds, and most probably contemporaneously with the outflow of lava which formed the overlying basaltic sheets.

Faults in this division.—Several faults occur in the division of the fossiliferous beds marked off by the two great depressions at Camus-Inivaig and Portree. One of these is a little to the west of Tanna Point, and brings down the upper sand-rock to the base of the lower bed of the Oolite, a downthrow of about 50 feet. A second occurs half a mile southwards, and brings the Inferior Oolite to the sea-level, and the sand-rock to the height of about 60 feet above it. There are also many slips. The secondary rocks have subsided *en masse*, without disturbance of the order of the beds, and brought

away with them an undercliff of the overlying trap, which, with castellated rocks and spiry pinnacles, almost rivals the Storr in picturesque grandeur. The disappearance of the beds here and at Portree harbour is not to be ascribed to the dip, but to their being cut off by the trap which also overlies them; this has been remarked by Dr. Macculloch.

Our next sections are taken from the area of the greatest development of these beds, that, namely, which extends from the north side of Portree harbour to the waterfall opposite Holm Islet.

Section IV.

Depressed below the sea-level all round Portree harbour, the beds rise again at Scoribrae at the north-east extremity of the bay, as shown in the sketch (Pl. XI. fig. 7), and, after a short course in this direction, are again cut off through a considerable space by the descent of the trap rock to the sea-level; rising again and thickening rapidly, they attain their greatest development nearly under the Tor-vaig mountain, which is 1280 feet in height. The beds represented in the figure belong to the Inferior Oolite, and are finely exhibited in this Scoribrae section. The following is the succession of the beds in descending order:—

		ft.	in.
1. Basalt.			
2. White gritty sandstone, the wall of an amphitheatre, for about...		80	0
3. Shelly limestones, fissile above and thick-bedded below; fossils, *Cidaris*, sp.? *Diastopora diluviana*, &c.		43	6
4. Argillaceous sand-rock, with large spherical limestone nodules; surface irregular; fossils numerous, among them are *Ammonites Humphriesianus*, *A. Strangwaysi*, *A. Murchisonæ*, *Belemnites giganteus*, *B. insculptus*, *B. gingensis*, *B. Blainvillei*, *Pecten lens*, *Cidaris Fowleri*		120	?
5. Sandy shales and fissile limestone	about	40	0
6. Marine arenaceous limestone			
7. Soft sandstones and fissile sandstones; *A. Murchisonæ*...	about	100	0
8. Calciferous sandstone, with calcareous bombs; *A. Murchisonæ*			
Sea-level		383	6?

The resemblance is manifest between these beds and C, B, and A, of Sect. II. The development is greater, and the fossils more numerous and remarkable.

Section V.

A little to the north of the highest point of the mountain, nearly over Prince Charles's Cave, as a small excavation in the Middle Lias is called, the following section was obtained: *order descending*.

Lias and Oolites.

	ft.
1. Basaltic covering.	
2. Black *Estheria*-shales.	
3. Basaltic sheet, interposed, rudely columnar	35
4. Blue flaggy subcrystalline limestone, weathering white, made up of shell-fragments lying in a crystalline paste, and containing *Neritina staffinensis*, small *Cyrenæ*, *Cyprides*, and seeds of *Chara*.	
5. Thin beds of black shale.	

		ft.
6.	Basaltic sheet (second interposed).	
7.	Light-coloured soft sandstones, with horizontal streaks of carbonaceous matter towards the base	30
8.	Black sandstones	30
9.	Basaltic sheet (third interposed)	?
10.	Sloping terrace covered with débris of sand-rock, &c.	
11.	Inferior Oolite.—A. A micaceous argillaceous sand-rock, with *Belemnites ventralis*, sand more prevalent above than below; beds traversed by hard lenticular masses of a semicrystalline limestone containing *Ammonites Murchisonæ* and *Lucina Wrightii*.	
	B. Finely laminated sandy micaceous shales, with *Belemnites ventralis*	
12.	Upper Lias.—Black shale, with limestone nodules at top, about	50
	The fossils are *Ammonites communis*, *A. falcifer*, *Inoceramus dubius*, *Pecten personatus*, and *Belemnites* of the same slender quadrate forms as occur in the alum shale of Yorkshire.	
13.	Middle Lias.—Close-grained hard calciferous sandstone, with intercalated, slightly ferruginous bands, and fossiliferous in the lower part chiefly. Thickness indeterminate, as it is continued under the sea-line. The leading fossils are, in the *Ammonites-spinatus* zone:—*A. spinatus*, rare; *Belemnites paxillosus*, common, *B. microstylus*; *Cryptænia expansa*, not rare; *Pecten æquivalvis*, common; *Plicatula spinosa*, common; *Cypricardia cucullata*, rare; *Mytilus scalprum*, rare; *Rhynchonella tetrahedra*, very common; *R. acuta*, rare; *Pentacrinus amalthei*, very common.	

The interposed basaltic sheets of this section are found to produce a remarkable alteration in the beds on both sides, similar to that already noticed in regard to the Camus Inivaig section, and which need not therefore be again described, showing that they are not of Oolitic age, but posterior and intrusive.

Section VI.

Another section a little to the south of the foregoing gave the following succession of beds in descending order:—

Oolites and Lias.

		ft.	in.
1.	Estuarine Series:—		
	Thin-bedded sandstone, greenish in colour, with lenticular calcareous masses: *Cyrena Brycei*.		
	Shell limestones	50	0
	Black shales.		
2.	Basaltic sheet	35	0
3.	Estuarine Series:—		
	Shales.		
	Earthy and shell limestones.		
	Shell-beds.		
	Blue argillaceous limestones.		
	Shell-beds and shell limestones.		
	Shales.		
	The whole series is very fossiliferous: *Neritina staffinensis*, *Mytilus*, sp.?, *Cyrena*, fish-remains, *Valvata*.		
4.	Carbonaceous Series:—		
	Black shaly sands and sandstones	100	0
5.	Basalt,		
6.	Shales and sandstones; height above sea about 300 feet.		
7.	Fissile shelly calciferous grits.		
8.	Gritty sandstone: *Ostrea sublobata*, *Belemnites gingensis*.		
9.	Massive sandstone with calciferous bombs. Belemnites.		
10.	Soft sandrock and massive sandstones.		

		ft.
11.	Argillaceous sands with hard courses.	
12.	Massive yellow and white sandstone with carbonaceous stains ...	10
13.	Shaly sandrock, with hard calciferous sandstone courses, and fossiliferous nodules towards top: *A. Murchisonæ, Bel. gingensis, Pecten Dewalquei, Inoceramus, Cucullæa cancellata, Cypricardia.*	
14.	Shaly sandrock, greyish and bluish yellow: *Belemnites confertus.*	
15.	Micaceous argillaceous sandrock, with hard lenticular masses above: *A. Murchisonæ, Bel. ventralis, Lucina Wrightii.*	
16.	Laminated sandy micaceous shales, with Belemnites.	
17.	Upper Lias	50 0
18.	Middle Lias.	

This section has a striking analogy with Section V. The two compared with Section IV. may be thus generalized:—

Generalized Section.	*Beds in detailed Sections.*	
	P. C. Cave.	*Scoribrae.*
Infra-Oxfordian Estuarine beds..................	3 and 1	wanting.
Bath Oolite series, ? Estuarine	4	2
Inferior Oolite.		
Upper series, Limestones	6–7	3
Middle series, Sandstones	8–12	4–8
Lower series, Shales and Sandstones...........	13–16	wanting.

On the western declivities of the basaltic cliffs which fall away towards the two lakes already mentioned, the upper beds of the Middle Oolite make their appearance, owing to the denudation of the overlying trap. The fossiliferous beds are shewn in a steep brow, facing northwards and south-east, of the south-east termination of Loch Fada, and also in the bed and banks of two or three burns which descend from the back of the precipices towards the central depression dividing them from the basaltic cliffs of the Storr range. The ridges of higher ground dividing the burns are formed of the common trap-rock. The fossiliferous beds consist, in ascending order, of reddish sands, fuller's-earth, sandy marls full of several species of *Cyrenæ*, and soft sandstones, over which is the trap. The deepest section, in the brow just mentioned, is about 20 feet; the others are only 2 or 3 feet; and sometimes it is merely an edge which emerges, or slabs appear in the bottom of a stream. Other fossils occurring here are *Neritina staffinensis* and *Melania? inermis.* At a still lower level, by the shores of the lakes, the marly beds with *Cyrena Brycei* and the oyster-bed of Loch Staffin, with *Ostrea hebridica,* make their appearance, and seem to form the basin of the lakes and much of the level tracts around them; calcareo-micaceous sandstone forms large rock-masses, pierced by a natural arch. At the north end of Loch Leathan it occupies the floor of the margin on two sides, and extends thence down the valley to the upper and lower cascades upon the stream forming the outlet. Here two of the basaltic sheets which enter the foregoing section (No. V.) are seen interposed among the Oolitic strata; and it is to their existence here that the cascades are due, as they have not been worn away. From their surface the water takes its headlong leap, and has excavated the soft strata below, in the case of the

lower fall, to an enormous depth. The basaltic sheets here also bear the same evidence to their later origin than the Oolitic deposits in the marked changes they produce on the sedimentary strata.

This central depression between the lofty cliffs on the shore and those of the range of the Storr, and in which the fossiliferous beds have not been before noticed, has a gentle diagonal swelling towards its southern part, almost due west from the top of Tor-vaig, which sends its waters to either side, north to the lakes and south to Portree. This summit-level is formed of trap, which extends thence to Portree, the fossiliferous beds not forming any connexion southwards with those of the shore-line. A considerable burn, whose lower course is through a deep trap gorge into the inner harbour of Portree, flows in its upper course close by the base of the Storr range, having its source in a lateral-glen opening upon the summit-level; and here, by its edge and in its bed, are several large blocks of the fossiliferous sandstones of the Oolite. The bed and banks consist entirely of huge sheets of trap; and the sandstone blocks are plainly not *in situ*. They must have been borne down in floods by some of the side burns already alluded to as showing these sandstones, or else transported hither by ice-action; some, indeed, appear too large for the transporting power of the burns even in heavy flood. The huge sheets of trap just mentioned have their surfaces both in the bed and banks, covered with fine markings such as are usually ascribed to the action of ice; they are nearly transverse to the course of the burn, ranging N.W. and S.E. (true), and therefore can hardly be ascribed to the action of stones borne along by the stream. It is a rare thing for trap surfaces in this district to bear such striæ.

The Loch-Staffin Beds.

Northward from the great waterfall, nearly opposite Holm Islet, the cliffs have but slight elevation, and the secondary beds, which are those of the middle and lower Oolite, small development. At Ru-na-Bhrarin there are great trap intrusions, and the beds are cut off by trap rocks occupying the shore-line (see map and sections, Pl. XI.); a little further north, however, not far from the waterfall of Loch Me-alt, the cliffs increase in height from the on-coming of beds higher in the series and a greater depth in the basaltic covering. These higher beds are those which have been called the Loch-Staffin beds (Murchison & Forbes, *ut suprà*), but which are now known, as above described, to occur in the Portree Section, and one bed at least in Raasay. A brief notice only is here required, and *that* mainly with the view of justifying our dissent from certain theoretical conclusions advanced by Professor E. Forbes.

The sea-line and tideway at Loch Staffin, and for many miles south-eastwards, unless where faults bring down the upper beds, are formed of a coarse crystalline dolerite consisting of felspar and augite, and sometimes dipyre: it is very hard and tough, and almost as rough on the worn surfaces as the hypersthene of the Coolins; it weathers a rusty brown, the colour being much deeper

within the tideway. The thickness at the highest part of the low cliff it forms was found to be 36 feet to half-tide level, total thickness unknown, as it descends below low water. On this doleritic sheet as a base, and between it and the common overlying trap, the Loch-Staffin beds are placed. It occupies the tideway to the point where the cliffs lower by the thinning of the upper beds and the denudation of the trap. The following Section was obtained under the high basaltic precipices about one mile east of the S.E. angle of the bay, and a little to the west of a fault which throws the beds 30 ft. down towards the east.

Section VII.

Loch Staffin (order descending).

1. Basaltic covering, 60 to 70 ft.
2. Limestone and dark shale, 3 to 4 ft.
   The upper bed next the basaltic rock is altered to the depth of 12 or 15 inches; the lower part of this is banded and cherty, like a blue-black Lydian stone, with crystalline shining surface, in parts; the upper part, that in contact, is not banded, and closely resembles the fine-grained lowest layer of the basaltic rock itself.
3. Sandstone bed, yellow, weathering white, 4 to 5 ft.; *Neritina staffinensis* and a short oval *Unio* occur.
4. Dark altered clays and shales, with shelly courses, 4 or 5 ft.; the fossils are *Potamomya Sowerbii*, *Cyrena Jamesoni*, *Pholadomya acuticostata*, *Perna Murchisoni*, *Corbula MacNeillii*.
5. Limestone band, 4 ft.
6. The *Ostrea-hebridica* bed, about 7 ft. This bed consists throughout, wherever it is seen, of a mass of oyster-shells cemented together by a muddy paste so closely that it is very difficult to obtain a perfect shell for determination of characters. The bed has great horizontal extent along these cliffs; and interrupted patches occur in several places eastwards connecting with the Portree cliffs; throughout it has the same structure. How inconceivably prolific must have been the oyster-beds of the period!
7. Sandrock, white and yellowish-white, about 25 ft.; with layers of carbonaceous matter parallel to the stratification, and pieces of jet. It contains angular bits of quartz, *Cyrenæ*, chiefly in the upper part, and *Neritina staffinensis*. It is traversed horizontally by huge dark-coloured bombs, effervescing briskly with acid, and leaving a sandy deposit where they decompose out.
8. Arenaceous limestones, 6 or 7 ft.
9. Thin-bedded flaggy limestones, 2 or 3 ft.
10. Black crumbling soft shales, 2 to 3 ft.
11. Grey calcareous and sandy shales, with *Cyrenæ* and oysters, probably 10 or 12 ft. Total of Oolitic beds about 70 ft.
12. The dolerite sheet extending under low water. The lowest Oolitic beds in contact with it are altered to the state of a saccharine marble; they adhere firmly to it; it insinuates itself among the beds in all directions, and entangles isolated portions of them in its mass. The evidence is thus even more complete than in the cases already given for the intrusive character of this rock, and its posteriority to the Oolitic series. Those portions of the limestones which are most altered still retain their carbonic acid, showing that the change took place under great pressure. The lowest series of beds probably exists underneath it.

It is difficult to bring any two sections of these beds into exact harmony: with certain beds of a normal character others of a varying

character and less persistent are interstratified; and perhaps no two observers would make the same exact division of the beds. There is, indeed, great difficulty in obtaining a true vertical succession; where the shore is passable there is a vast talus of fallen blocks, and faults and slips occur throughout; where the precipices rise sheer up out of the water, or with a narrow margin at their base, the telescope has to be appealed to, or one must judge what the beds aloft are by the débris of the margin. The section given by Prof. E. Forbes (Quart. Journ. Geol. Soc. vii. 106, 1851) is not in exact harmony with ours; but there is a general agreement: one exception is remarkable, the non-insertion of the *Ostrea-hebridica* bed, which is a striking feature of these cliffs, and, as above stated, is a mass of shells wherever it shows itself.

A section approximately the same as the above was obtained by standing on a projecting point of the cliffs near the waterfall, and looking back from $\frac{1}{8}$ to $\frac{1}{4}$ of a mile westwards, towards the Kilt or Kelt rock, famous along this coast for its curiously banded structure (*order descending*):—

Section VIII., *the Kelt Rock.*

1. The overlying columnar trap, 60 to 70 ft.
2. Indurated dark shaly beds.
3. Grey limestone and sandstone.
4. Dark shale with strong bands, *Ostrea-hebridica* bed.
5. Whitish-yellow sandstone, with nodules.
6. Shaly calcareous courses; *Cyrena*?
7. The underlying doleritic sheet.

The contrasted bands of rock in the lofty cliffs, the isolated basaltic pillars detached from the cliff behind by disintegration of the trap or subsidence of the secondary beds, the great faults (which change in a few feet the whole aspect of a precipice) render the coast-scenery very grand and interesting, though difficult to interpret. In many places the only way of reading the cliff-sections is by looking down upon them greatly foreshortened from the summit of an adjoining cliff. East of the Kelt rock there are several faults, the greatest of which seems to be that on which is the Loch-Me-alt waterfall, by which the secondary beds are cut off, and the overlying trap is brought down 40 or 50 ft. towards the east, so as to pass under the sea-line. In another fault a little to the west of this, the beds are seen 30 or 40 ft. higher on the east than on the west side. A little east of the waterfall the trap becomes completely denuded from the cliffs, and the highest of the secondary beds spread out over the fields and knolls to some distance inland, till the ground again rises and the basaltic covering comes on. The fossiliferous beds are seen in many places in the open fields, and in river-courses towards Ru-na-Bhrarin. The sketch Pl. XI. fig. 6 shows the manner in which this change takes place about half-a-mile to the eastward of Lake Me-alt. West of the lake the ground rises considerably, and the overlying trap is everywhere seen upon it continuous with that which forms the front of the highest cliffs of this coast, immediately west of the Kelt rock.

These sheets of trap are continuous across the high moors to the southwards with the trap of the central or Storr range, at the base of which beds of lignite are contained in the trap (see Map).

The road from the lake to Steinchol crosses this ridge; on reaching the bridge by the parish church and mill, and for some distance on both sides, up and down the burn, dark shales are interstratified with black basalt, and altered to the state of Lydian stone; they overlie and underlie the basalt, and are entangled in it in a most confusing way. The level of the stream at the bridge is not less than 60 ft. above sea-level; hence to the sea the stream runs on trap; and the bed must therefore be part of that which appears in the cliff at the S.E. side of Loch Staffin, under which the shale beds of the tideway pass.

This shale bed is the only one left of the whole series; and the overlying trap is divided from the doleritic sheet below by this thin shale bed only. The strata had here been denuded before the overlying trap was poured forth; the shale bed may thus have been entangled between the two traps, if contemporaneous; or if the doleritic were the earlier, we have the altered shale already prepared as the floor of the overlying trap. The trap cliff on the west (*i. e.* at S.E. angle of the bay) and the fossiliferous beds on the E. come together at the same level, at a depression where a paved road, the only passage from the shore, ascends to the top of the cliffs. The trap rock at the bridge and church is part of this great intrusive and depressed body of overlying trap, which can be traced continuously from the church till it ends in the cliffs. The explanation of these curious relations probably is, that, as the level tract at the head of the bay is occupied by Oxford clay, the lowest beds of the overlying trap invaded the strata on the east side at the first irruption of the fluid rock (see range of beds and map).

At about one mile west of the hotel, in the bed of a stream above the bridge, where the Uig and Duntulm roads diverge, the Oxford clay is seen in its normal state of a dark adhesive clay. Thence it stretches westwards by the base of the Quiraing mountain, and manifests its existence in many places, though not actually visible, by the tossed and broken surface, and the slips and subsidences on the new public road lately made, in the construction and conservation of which the engineer has found the greatest difficulties from this cause. The grand scenery of the Quiraing, with its subsided plateau and wondrous surrounding pinnacles, is a slip from the mountain-precipice, with all the parts in upright positions, owing to the lateral thrust exerted on the Oxford-clay beds, partly by the enormous weight of rock over them, but partly also, no doubt, by the hydrostatic pressure of columns of water which could obtain no passage through the clay beds.

The Uig Beds.

These beds consist of adhesive clay, dark shales, and arenaceous limestone. The nature of the ground is such that the beds are well seen only at the west angle of the bay, near the headland. There can

be no doubt, however, that the beds form the sides and bottom of the bay to some distance out, and run in against the trap precipice as far at least as the N.E. angle of the bay. Black mud and dark-coloured gravel are constantly cast up when, on rare occasions, the water is agitated, and form the whole tideway. The charm wanting to this lovely bay is a girdle of shining sand. Near the headland, where the beds first appear, a large dyke cuts through them, ranging nearly north, and greatly alters the limestone and shales.

The fossils of these beds are *Ammonites Jason*, *A. Lamberti*, *Belemnites Owenii*, *B. sulcatus*, *Littorina Meriani*, *Cucullæa concinna*, *Pecten arcuatus*, *Ostrea dilatata*, *Avicula inæquivalvis*, *Pholadomya Protei*, *Serpula tetragona*, *S. plicatilis*, *Nucula pollux*. Prof. Forbes does not mention the Uig beds or their fossils; nor is it probable that the place was visited by him; it will be seen, however, by a reference to his paper, that, of the Ammonites, one at least is most probably the same, the *A. cordatus* of Staffin, the *A. Lamberti* of Uig, and that the "Muricated *Turbo*" is the *Littorina Meriani* of Uig. But at Uig his *A. Vernoni* and *A. Eugenii* were not met with. The whole series at Uig is marine, the same as the fossils of the Oxford Clay in other countries.

Beds in other localities.

In the clays under the Quiraing mountain *Ammonites Lamberti* was found. The patches of strata at Duntulm are estuarine limestone and Oxford Clay, and have yielded *A. Koenigi* and *Cyrenæ* and a portion of the *Ostrea-hebridica* bed. I did not visit Mugstok; but, from the fossils found there by Sir R. Murchison, there can be no doubt that the beds are of the Middle Oolite; these were "*A. Koenigi* in masses, flattened *Tellinæ* and many *Belemnites*" (*ut. sup.* pp. 311, 322).

The strata at the head of the Loch-Bay inlet, in Vaternish, are estuarine shales and limestones; they come out in a thin stratum from under the trap at the head of the bay, and spread over the tideway, where a sheet of trap is seen among them. No vertical section is afforded; but as the beds dip seaward or nearly W.N.W. at 12° to 15°, and the edges are cut off, the structure is seen to some extent. The overlying trap alters the beds in a striking manner. The beds extend along the north side of the bay, being chiefly arenaceous limestones and sandy shales. They extend a little to the west of Vaternish village; but, the shore being low and formed of gently sloping cultivated fields on this side, no section is afforded of the whole series. To the west of a low bluff of trap, apparently a great dike, on which an old barrack stands, a low cliff or bank exhibits 7 feet of red sandy marl or soft sandstone, and over it a few feet of crumbling shale breaking into very small bits. No fossils were found in either. Over the shale the trap rock comes on; but the exact contact was not seen. (For a notice of the interesting fossils of this group see the Report.) Captain Macdonald, close to whose hospitable mansion this cliff is situated, conducted me to a singular cliff of trap-tuff on the shore to the west, 20 or 30 feet in height, and

overlain by ordinary trap. In the trap-tuff are imbedded a vast number of small pieces of altered, apparently fully mineralized wood, of which I procured a few specimens, in the hope of having the species of wood determined by slicing. The tufa dies out gradually westwards, and the ordinary trap succeeds.

No account of the Skye traps is attempted in this paper; the subject is too wide, and requires much careful study of the wild and difficult cliff-sections. Some general remarks on the relations of these various strata to one another, and to the intercalated traps, are reserved till an account has been given of the beds in Raasay.

A section of similar estuarine beds occurs at Vaterstein, already mentioned as the most westerly point where the Jurassic beds appear.

The following are the beds in descending order:—

Section IX. *The Vaterstein Beds.*

1. Shales and thin limestones, with *Paludina scotica*, *Cyrena Cunninghami*, fish, and thin sheets of basalt.
2. Shell-beds, *Ostrea hebridica* and *Cyrenæ*.
3. Shell limestones, marbles, *Cyrenæ*; shales and marls.
4. Sandy beds and marls, fossils few and obscure.

Total thickness about 120 feet.

Section of upper part (descending):—

	ft.	in.
1. Basalt.		
2. Altered shales and earthy limestones, fish-remains	3	7
3. Basalt	3	1
4. Earthy limestone	0	5–4
5. Blue hydraulic limestone, white on weathered face	0	5–7
6. Earthy limestone	0	4
7. Finely laminated black shales, fish and *Cyrena Cunninghami*	1	9
8. Paludinal marl and limestone (*P. scotica*)	1	4
9. Basalt	1	0
10. Shale	0	3
11. Basalt	0	10
12. Shale.		

Fossils:—*Cyrena Cunninghami*, *Ostrea hebridica* (?= *O. multiformis*, Koch and Dunker), *Melania inermis*, *Paludina Scotica*; fish the same as at Loch Bay.

Raasay.

The Jurassic strata occupy a much larger area in this island than on the coast of Skye opposite. The great mass of the central part of the island is formed of them; and they descend to the east coast in lofty mural precipices, through a distance of 7 or 8 miles; crossing the island south-west in a narrow band, they occupy a small area on the south coast, and on the west coast emerge at the sea-level from under the overlying rocks. At a short distance inland from this point they appear in a deep river-cutting, and in a small tract continuous with it, from which the overlying rocks have been swept away. At their north and south terminations on the east coast, and at the point on the west coast where they are visible, these strata rest on the unconformable beds of the Torridon or Cambrian Sandstone, which is continuous across the whole island along the north frontier of these beds, and occupies a small area in the

south-east corner of the island opposite to Scalpa, in the geology of which this sandstone figures so prominently. The Torridon Sandstone thus forms a basin whose south-west edge is depressed or broken off; and in this basin the Secondary beds have been deposited in a sea prolific of life, the deposits being accumulated to a maximum thickness of at least 1200 feet. They were broken through and overlain by igneous matter, which now appears in most parts of the island as grey felsite (felspar porphyry) and in a few places as the ordinary trap-rock, chiefly basalt or dolerite. These two rocks are seen in close proximity in only one place we know of, a small bay near the middle of the west coast, formed by the wearing action of the waves upon a basaltic dyke. The dyke appears at the head of the little bay; on the south side is the common trap-rock, on the north the felsite, which continues hence to occupy the coast, and extends over the whole of the western slopes to the central axis of the island, and stretches southwards to the south end of the island. Both rocks alike are seen to cut through in dykes, to overlie, and to alter, in both situations, the sedimentary deposits. A good example of both effects in the case of the felsite may be seen on the east side of the bay on which Raasay House is situated*.

The northern part of the island, north of Brochel Castle, and Rona a continuation of it, are composed of hornblendic gneiss, precisely the same in all its characters as that of the Long Island, and of the mainland of Ross and Sutherland, save that mica is always present. The lowest conglomerate bed of the Torridon sandstone is seen in fine section in a cliff north-west of Brochel Castle; and the rock south-east of the castle, on the shore, regarded as very peculiar by M'Culloch, who describes its structure most accurately, is but the lowest dark slaty unconglomerated part of the Torridon sandstone. The strata dip under the sandstone of the high cliff to the south. It struck me as remarkable that the fragments in the conglomerate of the Castle rock are all of quartz and Torridon sandstone; not a fragment could be detected either of the adjoining gneiss or of granite—as if the gneiss had not been exposed to disintegration when the conglomerate was forming. The map and sections (Pl. XI.) will show the distribution of the rocks of Raasay; and reference may be made to Dr. M'Culloch's description (vol. i. p. 239 *et seq.*) of the mineral structure of the rocks, and his account of their distribution, which is generally very correct. Our business here is chiefly with the fossiliferous beds, of which his account is most unsatisfactory. No section is given; and not one of the fossils is named by him, though the names of a few genera are suggested as those to which the specimens may possibly belong. The only fossils known to us as having been found in Raasay, before the collection now submitted to the Society was made, are those given by Sir R. Murchison, p. 367 of

* The kind hospitality of the late lamented proprietor of the Raasay estate, G. H. Rainey, Esq., and that of the present proprietor, G. Grant Mackay, Esq., enabled us to examine the island in a short time and with much ease and comfort.

the paper already quoted. These are *Ammonites Conybeari* (Sow. Min. Conch. tab. 131), *Gryphæa gigantea* (ibid. tab. 371), and *Plicatula spinosa* (ibid. tab. 245), all of which are said to have been found at Scrapidale, which is near the northern termination of the beds. They are merely named as having been found there; no mention is made of the beds, nor is any description or section given.

The Raasay sections present a succession very similar to those already given; it will therefore be unnecessary to multiply sections, or to dwell long on one.

Tracing the beds along the Hallaig shore, we find the Middle Lias occupying the coast-line till the stream is reached which descends to the sea on the south side of the headland Ru-na-Leac. This stream flows along the course of a fault, on the north side of which the Rhætic and Lower Lias are brought up against the Middle Lias and Inferior Oolite. These lowest Secondary strata, seen only at this place, occupy the whole of the bay included between Ru-na-Leac and a cliff to the north, which, for convenience of reference, I name Waterfall Cliff, conspicuous by the cascade which the Hallaig burn forms in its precipitous descent to the sea.

The base of the Ru-na-Leac cliff is a basaltic sheet, on which rest thick beds of breccias and conglomerates, composed of Torridon sandstone and quartzites, with included patches of coarse quartzitic sandstones, succeeded by finer conglomerates, coarse sandstones, and mottled sandstones. These rocks are unfossiliferous; but as they are conformable to the overlying Lower Lias, they may be regarded as of Rhætic age.

On the north side of the bay the Lower Lias occupies two scarped cliffs—the undercliff consisting, as far as seen, of compact blue limestones, weathering white, shales, and oyster-bands. The few fossils, in conjunction with the stratigraphical position, serve to fix the horizon as that of the zones of *Ammonites planorbis* and *A. angulatus*.

The higher cliff is composed of alternations of shales, gryphite beds, and earthy limestones below, passing up into sandy beds and calciferous sandstone, with the common fossils of the zone of *Ammonites Bucklandi*. The upper part of the cliff is a greenish-yellow calcareous sandstone, with scattered *Gryphæa arcuata*.

The dip of the Rhætic beds of Ru-na-Leac is as much as 20°; but that of the Lower Lias diminishes to 10° and 7°, with a breadth of outcrop of 3000 feet; the estimated thickness of the Rhætic and Lower Lias is 700 feet, 150 feet at least of which belongs to the Rhætic.

The higher beds of the Lower Lias in the Waterfall Cliff come down to the sea-shore, proceeding northward; and now a sudden change in the lithology and life takes place. The almost unfossiliferous sandstones are surmounted by soft micaceous shales, with lines of ironstone doggers, and crowded with well-preserved fossils, prominent among which are large specimens of *Ammonites armatus*, rugose examples of *Hippopodium ponderosum*, *Pholadomya decorata*, &c. These are succeeded by sandier and harder shales, with *Am-*

monites Jamesoni, and are the northern prolongation of the Pabba beds.

It is worthy of note that we have here a lower horizon to start from than in the Portree cliffs opposite.

This division presents in the cliffs here a great development. The following section was obtained a little to the north of the Hallaig cliffs almost under Dun-Cân, where the beds seemed to attain a maximum thickness (the order is descending):—

MIDDLE LIAS.

1. Yellow calciferous sandstone with nodules.
2. Bluish-green calciferous and
3. Shelly ferruginous sandstone.
4. Marly sandstone.
5. Grey marls.
6. Greenish-yellow sandstone with
7. Shaly partings.
8. Yellowish sandstone.
9. Greenish marly sand beds.
10. Greenish-yellow calciferous sandstone.
11. Greenish calciferous sandstone with indurated upper layer.

The whole section measures about 150 feet from the base of the Inferior Oolite to the sea-level.

Here No. 1 is the *Ammonites-spinatus* bed, Nos. 2–8 the *A.-margaritatus* beds, Nos. 9–11 the *A.-capricornus* bed. The fossils of No. 1 are *A. spinatus*, *Lima Hermanni*, *Pecten æquivalvis*, *Gresslya Seebachii*, *Ostrea cymbium*, *Avicula novemcostæ*, *Rhynchonella acuta* and *tetrahedra*, *Waldheimia resupinata*. In Nos. 2–8 inclusive, *A. margaritatus*, *Isocardia liassica*, *Pleuromya?*, *Pecten æquivalvis*, *Mytilus scalprum*, *Ostrea cymbium*, *Spiriferina rostrata*, *Rhynchonella tetrahedra*. In Nos. 9–11, *A. capricornus*, *Hippopodium ponderosum*, *Plicatula spinosa*, *Ostrea cymbium*, var. *Maccullochii*. In No. 10, *Modiola scalprum*, *Pleuromya ovata*, *Pinna folium*, *Plicatula spinosa*, *Cucullæa Münsteri*, *Pholadomya decorata*, *Pecten æquivalvis*.

No traces were found here of the shales of the Upper Lias; and the perpendicular form of cliff renders it impossible to get a good section of the Oolites. It was easy to see, however, that both the lower and upper series of the Inferior Oolite and the carbonaceous sandstones were present, but in somewhat greater development than in the Portree cliffs, owing to the great height. In the collection of Raasay fossils made by the late proprietor, Mr. Rainey, is a block of a white granular sandstone, comparable with specimens scattered on the Hallaig shore, containing *Ammonites gracilis*, Buckman, *Tancredia axiniformis*, and a smooth *Cerithium*. A rock of such a colour can be seen high up in these inaccessible cliffs. The whole extent of the cliff was followed with no better result. The Estuarine beds form the sloping brow between the top of the cliffs and the base of Dun-Cân; basaltic rock then comes on, and forms the whole of this picturesque crown-like hill, the highest point on the island, the elevation being 1443 feet. It is surrounded on all sides by the

Estuarine beds, including the *Ostrea-hebridica* bed, which a short distance to the west begins to be overlain by the grey felsite, and is seen nowhere else in the island. This one patch of Middle Oolite, with its isolated capping of trap, has a singular interest. It shows us, even more forcibly than the portions remaining in Skye, how great has been the denudation within our area, as well before the outflows of the trap began as in the period subsequent to their entire cessation. The central moor is traversed by many deep, broad, and winding clefts, in which water will not lie, and by others less wide, which render great caution necessary in crossing this part of the island. Here many Middle-Lias fossils were obtained. This Middle Lias is the chief feature of Raasay; the development is great, and the fossils abundant, as will be seen by inspecting the lists and Reports. This member of the series occupies the moor and hill-top southwards to the road leading from the mansion-house to Hallaig; it is well seen all along the north side of the road, and in the bed of the stream, and abounds here in fossils. These beds descend the glen, and pass down to the south coast, whose beds, overlain and cut through by the felsite, are of the Middle Lias.

The beds on the west coast occur in a steep sea-cliff, opposite to Portree (see the section across the island, Pl. XI., fig. 3); they consist of superior oolite sandstones and flaggy gritty limestones, surmounted by the soft sandstones of the Bath-Oolite series.

Summary and Conclusion.

The facts stated in the preceding detailed sections may now be restated in brief summary, and the general theoretical results set forth.

The sections viewed in connexion give a series of beds within the area, ascending from the lower part of the Lower Lias to the middle part of the Middle Oolite. The base on which the whole series reposes is the same wherever that base is exposed to view, namely the Torridon or Cambrian sandstone which succeeds the hornblendic gneiss. Has the vast intervening series never existed here? or, having once existed, has it been swept away? In attempting to answer this question we must look to other parts of the same physical area—that placed under like conditions and the theatre of similar events; we find this in Mull and the north-east of Ireland; and there we see that between the Cambrian sandstone and the Lias there intervene the Silurian, fragments of the Devonian and Carboniferous beds, fragmentary Permian, and fully developed Triassic beds. In Mull the Liassic series rests on a base of Old Red, and underneath the overlying trap are beds representing the chalk. In the north-east of Ireland the lower lias, greensand, and chalk only are found. Now it has been shown by the author of the present paper (Geol. Trans. 2nd ser. vol. v. p. 69), and his friend Mr. Tate (Q. J. G. S. vol. xxiii. p. 298), that this series, reposing along its southern limit on the Rhætic beds and trias, "tails off" northwards by denudation, bed after bed in ascending order disappearing, until at length only a thin band of chalk separates the overlying trap

on one side of a valley from mica-slate, and on the other from a boss of coarse red granite rising through the slate. It seems a legitimate conclusion from the occurrence of these breaks in the usual succession in one part of the Liassic area, that denuding causes may have similarly acted in another, and so have removed the intermediate formations from over the Cambrian sandstone in Skye and Raasay before the Jurassic beds were laid down.

The Lower Lias has been identified on Loch Sligachan and in Raasay, the existence of the Rhætic beds in the latter rendered almost certain, the Middle Lias traced in its full development northwards, and the Upper Lias traced through a long horizontal distance; the members of the Inferior Oolite have been distinctly separated, and the characters shown to be persistent; the area of the Middle Oolite has been extended, and its beds traced from the Loch-Staffin cliffs by the interior part of the country round the base of the Storr mountain into the area of the Portree Oolites, where the characters and fossils are identical. From beds whose fossil contents were before unknown, a large collection of fossils, embracing many new species, has been obtained, whose relations with those of other areas present many points of interest.

The lithological characters of the beds have a remarkable similarity throughout, and a close resemblance to the structure of the beds on the Yorkshire coast, as shown in the character of the great sandy Oolite, with its included coal-beds and jet, those of the Upper Lias, though of such insignificant thickness, and the striking similarity of the Oxford clay. All this indicates a wonderful resemblance in the sediments carried down into two areas divided by half the length of Great Britain, and a striking similarity in the productions of land-surfaces so widely separated, by which the coal- and jet-beds, the *Cycas* and the fern were supplied. Where, we may ask, lay the land which supplied these growths, and the vast alternations of argillaceous, sandy, and calcareous beds which we find within the area? That changes took place in the land-surfaces themselves during the period of the deposits is evident by the change from marine to estuarine and almost freshwater conditions, of which the evidence remains to us in the marine fossils of Staffin, the estuarine towards Portree, and those of a freshwater character at Loch Bay and Vaterstein. Oscillations of the land, the deepening and shallowing of water would soon bring about such a change in the fauna.

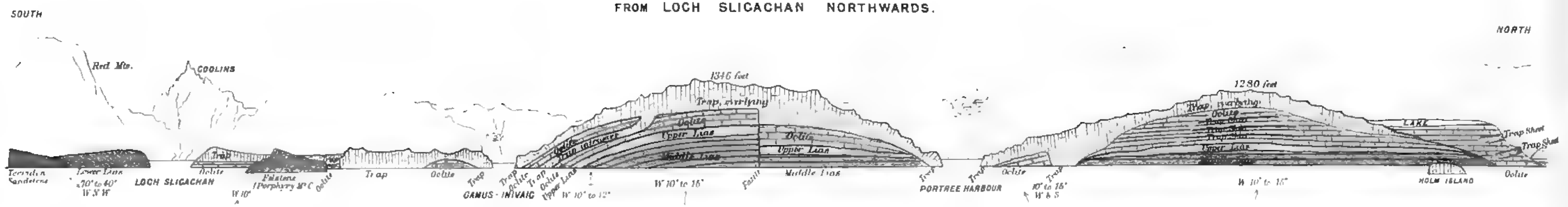
And, lastly, as regards the intrusive sheets of trap, it appears from the facts stated regarding the three sections on which they are met with, that they are of later age than the Jurassic beds amid which they lie; the beds on either side are in every case altered by them; they are thus certainly not of Oolitic age, as has been supposed; that is, they were not injected after one bed had been thrown down, and before the next overlying was deposited. Of how much later a date they may be than the Oolitic strata it is difficult to decide, the Camus-Inivaig section being the only one which affords any evidence. Doubtless they were formed at great depths; and to this their uniformly crystalline character may be due, as well as to

Fig. 1.

MAP OF THE ISLANDS OF SKYE AND RAASAY.

Fig. 2.

COAST SECTION OF ISLE OF SKYE FROM LOCH SLIGACHAN NORTHWARDS.



CONTINUATION OF Fig. 2.

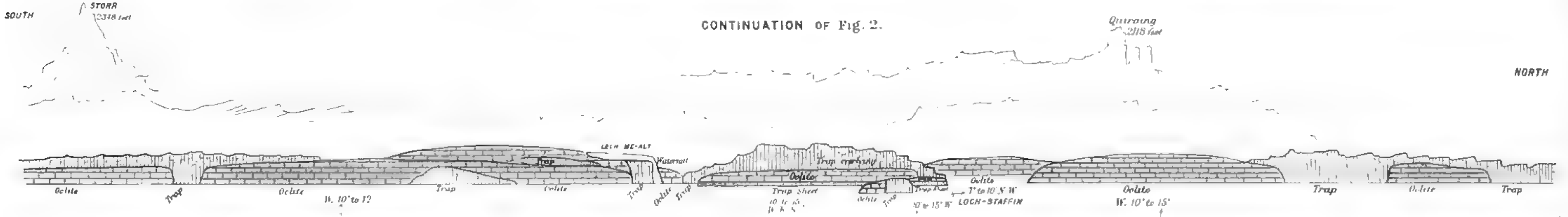


Fig. 3.

CROSS SECTION THROUGH ISLE OF RAASAY.

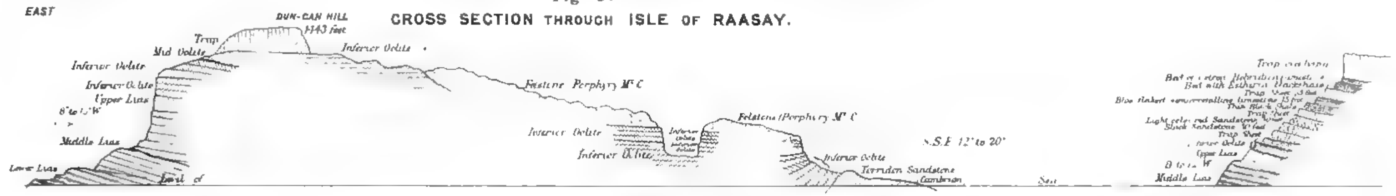


Fig. 4.

THE SAME CROSS SECTION AS Fig. 3 CONTINUED THROUGH SKYE

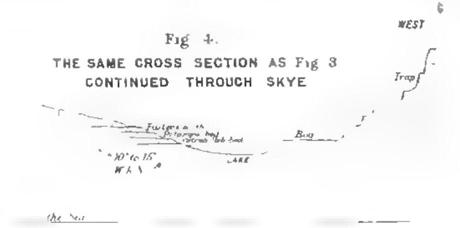


Fig. 6.

SECTION EAST OF LOCH-MEALT.

SHEWING THE DENUDATION OF THE TRAP.

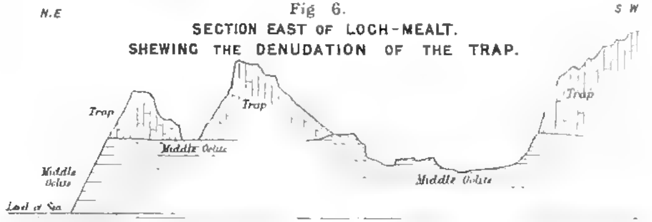


Fig. 7.

COAST SECTION.

SHEWING THE RISE OF THE JURASSIC BEDS.

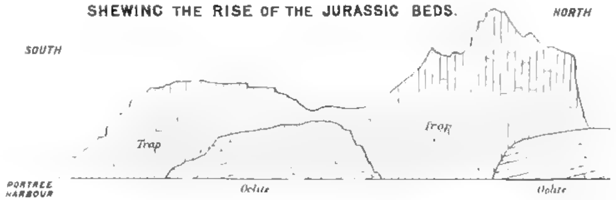
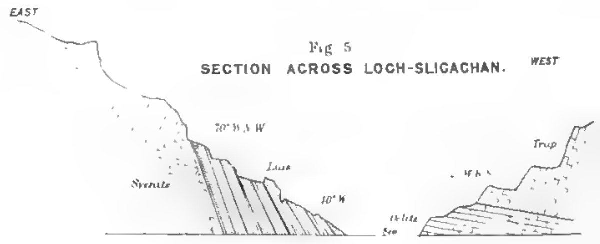


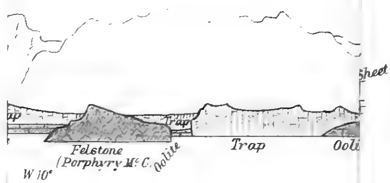
Fig. 5.

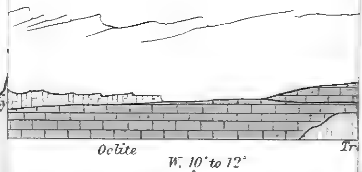
SECTION ACROSS LOCH-SLIGACHAN.

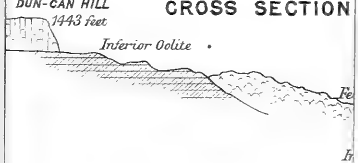


MAP OF THE ISLAN

NS





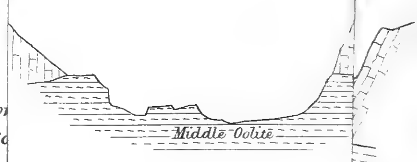


CROSS SECTION

Fig: 6.

ST OF LOCH-MEALT.

UDATION OF THE TRAP.



the nature of the cooling surfaces, by which the heat of fusion parted from them. Yet we often find true basalts, syenites, and greenstones upon the existing surface, as well as amygdaloids, while the latter are often at the base of deep sections; and such differences are therefore not of much value. The basaltic sheet forming the top of the Staffin cliffs, is certainly not interposed. It is continuous and superficial inland to the base of the Storr range, of which it is but one of the basement-sheets, superior to all the Oolitic strata, and a member of the overlying series.

Finally, then, when we consider that the sheets of trap intercalated in all our sections alter the sedimentary strata both above and below, and that the bed interposed in the Camus-Inivaig section emerges at the top of the section and becomes continuous with the overlying trap, the conclusion is forced upon us that the various intercalated sheets belong to the period of the outflow of the overlying trap series.

EXPLANATION OF PLATE XI.

Fig. 1. Geological sketch map of the islands of Skye and Raasay.
2. Cliff-section of the coast of the Isle of Skye, from Loch Sligachan northwards.
3. Cross section through the Isle of Raasay.
4. Cross section in the line of fig. 3, continued through Skye.
5. Section across Loch Sligachan.
6. Section east of Loch Me-Alt, showing the denudation of the trap.
7. Coast-section, showing the rise of the Jurassic beds.

APPENDIX.—*On the* PALÆONTOLOGY *of* SKYE *and* RAASAY. By RALPH TATE, Esq., Assoc. Linn. Soc., F.G.S.

I. PALÆONTOLOGICAL HORIZONS, SKYE, &c., AND LISTS OF FOSSILS.

RHÆTIC?

The conglomerates, quartzitic sandstones, and brick-red and greyish sandstones, forming the cliff Ru-na-Leac, may be of this age. No fossils observed.

LOWER LIAS.

Hettangian Series(=zones of *Ammonites planorbis* and *A. angulatus*).—The blue argillaceous limestones and indurated shales constituting the under cliff on the north side of Ru-na-Leac Bay, I regard as the basal portion of the Lower Lias. The following fossils were obtained:—

Natica, sp.	Pecten pollux, *D'Orb.*
Ostrea irregularis, *Münst.*	Astarte Gueuxii, *D'Orb.*
Plicatula Deslongchampsi, *Terq.*	Lima punctata, *Sow.*
Perna infraliasica, *Quenst.*	Mytilus Hillanus, *Sow.*

Beds 1 to 4, Geikie's section, may probably belong here. The fossil evidence, however, is inconclusive, the coral being peculiar, and the other two species recorded from these beds occurring elsewhere in the zones of *A. angulatus* and *A. Bucklandi*, and even

higher. A sandstone on the north slope of Ben Glamaig, yielded me impressions of *Terquemia arietis,* Quenst.

Zone of *Ammonites Bucklandi.*—The rocks of this series present the characteristics of the Yorkshire type of the *Lima* or *Bucklandi* beds of the south of England, consisting chiefly of shales with shelly tops and thin earthy limestones, contrasting with the compact blue limestones of the underlying series. The section opposite exhibits the lithological variations of this horizon in the Waterfall Cliff, Hallaig, Raasay. Order ascending.

The greyish and yellowish-coloured calciferous sandstones which form the remaining portion of the cliff, contain throughout scattered *Gryphæa arcuata*; no other fossils observed.

I place here beds 5 to 11 of Geikie's section, as a few characteristic fossils of this horizon were obtained from beds 5, 6, 8, and 10; they are given in the subjoined Table.

The limestone of Loch Sligachan also belongs here.

Fossils of the Bucklandi-*beds.*

R, Raasay; B, Broadford; and S, Sligachan.

R, B.	Ammonites bisulcatus, *Brug.*	R, B.	Lima pectinoides, *Sow.*
R, B.	—— Sauzeanus, *D'Orb.*	R.	—— gigantea, *Sow.*
R, B.	—— difformis, *Em.*	R, B.	Macrodon hettangiensis, *Terq.*
R.	—— sinemuriensis, *D'Orb.*	R, B.	Pinna Hartmanni, *Goldf.*
R.	—— ziphus, *Ziet.?*	S, B.	Avicula novemcostæ, *Brown.*
R, S.	Belemnites infundibulum.	R, B.	Pecten Hehlii, *D'Orb.*
R.	Pleurotomaria similis, *Sow.*	R.	—— Thiollieri, *Martin.*
R, B.	Cryptænia polita, *Sow.*	R.	—— textorius, *Goldf.*
R, B.	Eucyclus elegans, *Goldf.*	R.	Mytilus Gueuxii, *D'Orb.*
R.	——, sp.	R.	Unicardium cardioides, *Phillips.*
R.	Turbo solarium, *Piette.*	R.	Pleuromya galathea, *Ag.*
R.	Phasianella Morencyana, *Terq. & Piette.*	R.	—— liasina, *Ag.*
B.	Ostrea irregularis, *Münst.*	R.	Astarte Gueuxii, *D'Orb.*
R, B.	—— arcuata, *Lamk.*	B.	Rhynchonella plicatissima, *Quenst.*, et var. ammonitica.
R, B.	Cardinia Listeri, *Sow.*	R.	Waldheimia perforata, *Piette.*
R.	—— crassiuscula, *Sow.*	R.	Spiriferina Walcotti, *Sow.*
B.	Cardium Philippianum, *Dunker.*	R.	Cidaris Edwardsii, *Wright.*
B.	Lima punctata, *Sow.*	B.	Chemnitzia, Cerithium, and Pentacrinus, spp.

Middle Lias.

Zone of *Ammonites Jamesoni.*—"The dark grey or brown sandy micaceous shales (with small doggers and shelly masses) of Pabba, beyond Corry, and around the Syenite of Beinn Bhuidh, as far as the entrance to Scalpa Sound" *, most undoubtedly are correlative with the shale occupying the base of Huntcliff, Yorkshire, inasmuch as they contain the same series of fossils, and the other beds regularly superimposed contain identical species each to each. Similar beds are exposed on the banks of the burns by the roadside, two miles from Raasay House on the way to Hallaig, and elsewhere on the Island of Raasay.

* Geikie, Quart. Journ. Geol. Soc. xiv. p. 5.

Lithology.	Thickness.		Fossils.
	ft.	in.	
1. Indurated shales	7	0	
2. Indurated shales, with impure limestone courses.	4	9	
3. Gryphite-bed	1	0	*Gryphæa arcuata, Rhynchonella ammonitica, Ammonites sinemuriensis.*
4. Indurated shale	0	6	*Pecten textorius, Cidaris Edwardsii.*
5. Gryphite-bed	0	6	*Gryphæa arcuata, Pinna Hartmanni.*
6. Shale	0	6	*Belemnites infundibulum.*
7. Gryphite-bed	0	9	*Gryphæa arcuata, Pecten textorius, Pentacrinus.*
8. Indurated shale	1	0	*Belemnites infundibulum.*
9. Gryphite-bed, with shale parting. (Top of 1st scar.)	1	2	*Gryphæa arcuata, Lima gigantea, Spiriferina Walcotti.*
10. Impure indurated limestone. (2nd scar.)	4	1	*Belemnites infundibulum, Gryphæa arcuata.*
11. Soft shale	0	4	
12. Massive impure limestone	0	10	
13. Gryphite........................	0	10	*Ammonites bisulcatus, Rhynchonella ammonitica, Pinna Hartmanni, Cardinia crassiuscula.*
14. Soft shelly shales	2	0	*Lima pectinoides, Pecten Thiollierei, Rhynchonella ammonitica, Waldheimia perforata,* many Gasteropods.
15. Sandy shales and limestone	2	10	
16. Sandy shales and gryphite-bed. (3rd scar.)	2	7	
17. Sandy shales	1	3	*Pleuromya galathea, Spiriferina Walcotti.*
18. Gryphite-bed	0	3	
19. Sandy shales	1	6	*Gryphæa arcuata, Lima gigantea, Spiriferina Walcotti, Belemnites.*
20. Shale, with line of black nodules.	2	7	
21. Shale	1	8	*Ammonites Sauzeanus.*
22. Indurated shale	2	3	
23. Gryphite-bed, very fossiliferous.	0	7	*Cardinia Listeri, Pleurotomaria similis, &c.*
24. Indurated shale................	1	10	
25. Shales and thick masses of *Rhynchonellæ.*	4	0	*Cardinia Listeri, Lima pectinoides.*
26. Sandy shales	6	0	Scattered *Gryphæa arcuata.*
27. *Gryphæa*-beds (sandy matrix)	15	6	
28. { Shaly sands ....; *Gryphæa*-beds ....; Sandy beds .... }	9	6	*Ammonites bisulcatus.*
29. { Sandy limestone ....; Sandstone......................; Calciferous sandstone ...... }	15	0	*Spiriferina Walcotti, Rhynchonella ammonitica, Pholadomya Fraasii, Pleuromya galathea, Lima pectinoides, Ammonites bisulcatus.*
Total	92	7	

On the Hallaig shore the *Jamesoni*-beds are underlain by soft, dark-coloured, micaceous shales, with *Ammonites armatus*; though the lithological features are sufficiently distinct, yet the community of species is so great that there is not much value in detaching the beds with *A. armatus* from those with *A. Jamesoni*.

On the south-east shore of Church-Town Bay, Raasay, the *armatus* shales are altered by porphyritic syenite, which intrudes and overlies them. *Ammonites tardecrescens*, *Pinna folium*, *Pholadomya decorata*, and *Avicula novemcostæ* are the only fossils noted.

List of Fossils from the Armatus- *and* Jamesoni-*beds of Pabba and Raasay.*

Ammonites Jamesoni. Pabba, *Wright*, *R. T.* Hallaig Road, Raasay, *R. T.*
—— armatus. Raasay, *R. T.*
—— polymorphus. Raasay, *R. T.*
—— brevispina. Pabba, *Wright.* Raasay, *R. T.*
—— tardecrescens. Raasay, *R. T.*
—— Davœi, *Sow.* Pabba, *Wright.*
Belemnites elongatus. Pabba, *Wright.* Raasay, *R. T.*
—— paxillosus. Pabba, *Wright.*
—— elegans. Raasay, *R. T.*
—— breviformis. Pabba, *Wright.*
—— clavatus. Pabba, *R. T.*
Chemnitzia Blainvillei, *Benz.* Pabba, *R. T.* Raasay, *R. T.*
Cerithium Slatteri. *Tate.* Raasay, *R. T.*
Tectaria imbricata, *Sow.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*
Pholadomya decorata. Pabba, Raasay, *R. T.*
—— ambigua. Pabba, *Wright.* Raasay, *R. T.*
Pleuromya ovata, *Röm.* Pabba, *R. T.* (? P. unioides, *Wright*). Raasay, *R. T.*
—— scotica, *Wright.* Pabba.
Unicardium Ianthe, *D'Orb.* Pabba, ? U. cardioides, *Wright.* Raasay, *R. T.*
Pinna folium, *Y. & B.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*
Mytilus scalprum, *Sow.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*
—— numismalis. Raasay, *R. T.*
Leda Zieteni, *Brauns.* Raasay, *R. T.*
—— galathea, *D'Orb.* Raasay, *R. T.*
Cardinia attenuata, *Stutch.* Raasay, *R. T.*
Avicula novemcostæ, *Br.* Pabba, *R. T.* Raasay, *R. T.*
Lima Hermanni, *Ziet.* Pabba, *Wright* & *R. T.*
—— eucharis, *D'Orb.* Pabba, *R. T.*, ? L. gigantea, *Wright.*
Limea acuticosta, *Goldfuss.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*
Inoceramus ventricosus, *Sow.* Pabba, *Wright.* Raasay, *R. T.*
Pecten æquivalvis, *Sow.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*
—— liasinus, *Nyst.* Pabba, *R. T.*
Plicatula spinosa, *Sow.* Pabba, *Wright* & *R. T.*
Gervillia Maccullochii, *Wright.* Pabba, *Wright.*
Gryphæa cymbium, *Lamarck.* Pabba, *Wright* & *R. T.*
—— obliquata, *Sow.* Pabba, *Wright.* Raasay, *R. T.*
Hippopodium ponderosum, *Sow.* Pabba, *R. T.* Raasay, *R. T.*
Astarte striatosulcata, *Röm.* Pabba, *R. T.*
Arcomya vetusta, *Phil.* sp. Pabba, *R. T.*
Cucullæa Münsteri, *Goldfuss.* Raasay, *R. T.*
Cardium truncatum, *Sow.* Raasay, *R. T.*
Cardita multicosta, *Ph.* Raasay, *R. T.*
Rhynchonella tetrahedra, *Sow.* Pabba, *Wright* & *R. T.* Raasay, *R. T.*

Rhynchonella furcillata. Raasay, *R. T.*
—— variabilis. Raasay, *R. T.*
Waldheimia numismalis. Raasay, *R. T.*
Spiriferina oxyptera, *Buvig.* Raasay, *R. T.*
—— verrucosa. Raasay, *R. T.*
Pseudoglyphea, n. sp. Raasay, *R. T.*
Ditrypa circinatum, *Tate.* Pabba and Raasay, *R. T.*
—— quinquesulcatum, *Goldfuss.*, sp. Pabba, Raasay, *R. T.*
Pentacrinus robustus, *Wright.* Pabba, *Wright.*
—— lævis, *Miller.* Pabba, *Wright & R. T.*

The beds superior to the zone of *A. Jamesoni* are exposed in the upper part of stream-courses on the Hallaig moor, and form a grand section on the east coast of the island, displaying a gradual passage from argillaceous sediments into the calcareo-arenaceous rocks which constitute so striking a feature in the lithology of the Middle Lias of this area.

A section of about 150 feet exhibits the following variations of zones.

Ammonites spinatus.

1. Yellow calciferous sandstone, with ferruginous nodules.

Ammonites margaritatus.

2. Bluish-green fissile calcareous sandstone.
3. Shelly ferruginous sandstone.
4. Marly sandstone.
5. Grey marls.
6. Greenish-yellow sandstone with shaly partings.
7. Yellowish sandstone.
8. Greenish marly sand beds.

Ammonites capricornus.

9. Greenish-yellow calcareous sandstone.
10. Greenish calcareous sandstone, with indurated tops.

Zone of *Ammonites capricornus.*—The upper part of this zone is the base of the cliff section on the east coast of Skye. At the south-east side of Portree harbour it consists of hard micaceous sandy calcareous shales, with lines of spherical calcareous nodules.

Fossils of the Zone.

Ammonites capricornus. Raasay.
—— Davœi. Portree.
—— Henleyi. Raasay.
Pecten æquivalvis, *Sow.* Portree.
—— liasinus, *Nyst.* ,,
Avicula novemcostæ. ,,
Limea acuticosta. ,,
Unicardium Ianthe.
Cardium truncatum.
Pholadomya ambigua, *Sow.* Portree, Raasay.
—— decorata. Raasay.
Pleuromya ovata, *Röm.* Portree.
Mytilus scalprum, *Sow.* Raasay.
Arca Stricklandi, *Tate.*
Cypricardia cucullata, *Goldf.*
Inoceramus ventricosus.

Ostrea cymbium, *Lamk.* Portree.
—— obliquata. Raasay.
Hippopodium ponderosum. Raasay.
Pinna folium. Raasay.
Cucullæa Münsteri. Raasay.
(From passage beds.)
Rhynchonella tetrahedra. Portree.
—— variabilis. Portree.

Zone of *Ammonites margaritatus.*—On the south side of Portree Harbour this palæontological horizon is constituted of bluish micaceous sandstones thinly bedded, and containing lines of very large blue calcareous nodules and septaria.

FOSSILS.

Ammonites margaritatus. Raasay, Portree.
Belemnites umbilicatus. Raasay.
—— breviformis. Raasay.
—— longissimus. Raasay.
Tectaria Gaudryana. Portree.
Chemnitzia Blainvillei. Portree.
Pecten æquivalvis. Portree, Raasay.
—— liasinus. Portree, Raasay.
—— strionates. Raasay.
Avicula novemcostæ. Portree, Raasay.
—— cygnipes, Raasay.
Lima Hermanni. Raasay.
Limea acuticosta. Portree.
Pleuromya ovata. Raasay.
Pholadomya ambigua. Raasay.
Mytilus scalprum. Raasay.
Leda graphica. Raasay.
Ostrea cymbium. Raasay.
Plicatula spinosa. Raasay.
Cypricardia cucullata. Raasay.
Macrodon liasinum. Raasay.
Arcomya arcacea, *Seeb.* Raasay.
Ceromya liassica, *Moore.* Raasay.
Lingula Voltzii. Raasay.
Rhynchonella acuta. Raasay.
—— subconcinna. Portree.
—— tetrahedra. Raasay.
Terebratula punctata. Raasay.
Spiriferina Münsteri. Raasay.
—— rostrata. Raasay.
Eryma propinqua, *Opp.*?
Pentacrinus amalthei. Portree.

Zone of *Ammonites spinatus.*—Hard calcareous sandstone, yellowish-grey, thick-bedded, exterior surface honeycombed, contains large reddish-brown lenticular and indurated masses on the south side of Portree Harbour; it measures about 40 feet in thickness. In this section the upper 5 feet are bluish and more calcareous, and thus approximate to the basal limestone of the Upper Lias. Elsewhere it presents the same lithological features, and the same characteristic species.

FOSSILS.

Ammonites spinatus (v. c.), A. margaritatus (r.).
Belemnites paxillosus, B. elongatus, clavatus, microstylus.
Cryptænia expansa.

Pecten æquivalvis,	P. liasinus.
Lima Hermanni,	L. scabricula, *Tate.*
Plicatula spinosa,	Ostrea cymbium et *var.* gigantea.
Avicula novemcostæ,	Mytilus scalprum ?
Gresslya Seebachii,	Cypricardia cucullata.
Astarte amalthei.	
Terebratula punctata,	Waldheimia resupinata.
Rhynchonella acuta,	R. tetrahedra.
Ditrypa quinquesulcatum,	Pentacrinus amalthei.

Upper Lias.

This formation constitutes a thin band of argillaceous material, strongly distinguished from the underlying Middle Lias, but showing in some localities, as over Prince Charles's Cave, gradation into the superimposed Oolite.

On the south side of Portree Harbour the following fossils were obtained from the beds in Section I.

	Ft.	in.
Inferior Oolite, sandstone.		
1. Blackish-blue argillaceous limestone, with *Ammonites communis*...	0	4
2. Black shales	3	0
3. Line of nodular blue limestone, showing oolitic structure in part and pyritous—*Ammonites communis* and *A. falcifer* in abundance and of large size........	0	3
4. Stiff black shales, slightly micaceous, with *A. communis*, *A. falcifer*, *A. heterophyllus*, *Inoceramus dubius*, and jet	8	0
5. Brown crystalline limestone with *Ammonites communis*........	0	6
6. Friable black shale, with *A. communis*........	1	6
7. Compact limestone, blue argillaceous, with *A. communis*	1	3
8. Finely laminated black shale with *A. communis* and *A. bifrons*...	0	9
Middle Lias, calciferous sandstone.		
Total...	15	7

Fossils.

Ammonites communis, *Sow.*	Belemnites inornatus ?
—— falcifer, *Sow.*	Onustus heliacus, *D'Orb.*
—— heterophyllus, *Sow.*	Tectaria capitanea, *Goldf.*
—— striatulus, *Sow.*	Natica pilula, *Tate.*
—— variabilis.	Inoceramus dubius, *Sow.*
—— bifrons, *Brug.*	Pecten personatus, *Ziet.*
Nautilus striatus, *Sow.*	Hinnites tumidus, *Ziet.*
Belemnites Voltzii.	Nucula subglobosa, *Röm.*

Lower Oolite.

1. *Inferior Oolite* (*Lower Series*).

Dark grey sandstone courses alternating with micaceous shaly sands stained with carbon.

The majority of the fossils were collected in the bottom bed; but *Ammonites Murchisonæ* occurs throughout, and is abundant in brown marly nodules in sandy shale, near the top of the series; the Belemnites are also diffused, and are plentiful in the sandy beds.

Fossils.

Ammonites Murchisonæ.	Dentalium entaloides, *Desl.*
—— subradiatus, *Sow.*	Pleurotomaria, sp.

Ostrea, sp.
Lucina Wrightii, *Op.*
Pecten Dewalquei, *Op.*
Avicula inæquivalvis, *Sow.*
Pleuromya jurassi.
Inoceramus amygdaloides (?), identical with a shell in the Inferior Oolite at Sully, *R. T.*
Nucula Hammeri, *Defr.*
Belemnites pectinatus, n. sp.
—— confertus, n. sp.
—— giganteus.
—— gingensis, *Oppel.*
—— ventralis.
—— insculptus, *Phil.* vel.
—— rostriformis, *Quenst.*
Cucullæa cancellata.

2. *Inferior Oolite* (*Middle Series*).

Red-yellow varying to white sand-rock, grey where resting on the lower series, with plant-remains, and calciferous sandstones and shales.

Fossils.

Ammonites Humphriesianus.
—— comensis.
Belemnites parallelus, *Phil.*
—— aalensis.
—— giganteus.
—— Blainvillei.
Pecten Dewalquei.
Pecten lens.
Terebratula perovalis.
Rhynchonella concinna?
Ostrea sublobata.
Cidaris Fowleri.
Obscure cycads and ferns.

3. *Inferior Oolite* (*Upper Series*).

Fissile shelly crystalline limestones and gritty limestones.

Fossils.

Avicula costata.
Ostrea Sowerbyi.
Lima gibbosa.
Arca, sp.
Terebratula lagenalis?
Rhynchonella concinna?
Diastopora diluviana?

Middle Oolite.

1. *Estuarine Series* (*infra-Oxfordian*).

! Melania? inermis, *Tate*: Vaterstein, Tor-Vaig, North Cliffs, Portree.
! Neritina arata, *Tate*: Loch Bay, Dunvegan.
! —— staffinensis, *Forbes*: Staffin, Tor-Vaig, Loch Bay, North Cliff, Portree.
! Valvata præcursor, *Tate*: North Cliff, Portree.
! Paludina scotica, *Tate*: Loch Bay, Dunvegan, Vaterstein.
! Leptoxis trochiformis, *Tate*: Loch-Bay.
! Hydrobia caledonica, *Tate*: Loch Bay, Dunvegan.
—— præcursor, *Sandberger* (=H. conulus, *Forbes*, non *Lamk.*): Staffin.
Ostrea hebridica, *Forbes* (=O. multiformis, *K. & D.*): Vaterstein, Staffin, Tor-Vaig, Duntulm, Loch Bay, Dun-cân, Raasay.
Perna Murchisoni, *Forbes*: Staffin, North Cliffs, Portree.
! Anomia æstuarina, *Tate*: North Cliffs, Portree.
! Mytilus cuneatus, *Sow.*: Loch Bay, Dunvegan.
! —— sublævis, *Sow.*?: Loch Bay, Dunvegan.
! —— (*cf.* lithodomus, *K. & D.*): North Cliffs, Portree.
—— (*cf.* cuneatus, *K. & D.*): North Cliffs, Portree.
Trigonia tripartita, *Forbes*: Staffin.
Unio? staffinensis, *Forbes*: Staffin.
Cyrena (Miodon) Jamesoni, *Forbes*: Staffin.
—— (M.) Cunninghami, *Forbes*: Staffin, Vaterstein, North Cliffs, Portree.
! —— (M.) Brycei, *Tate*: Tor-Vaig, Staffin, Loch Bay.
Cyrena arata, *Forbes*: Staffin.
—— MacCullochii, *Forbes*: Staffin.
! —— cucullata, *Tate*: Loch Bay, Dunvegan.

Potamomya? Sowerbii, *Forbes*: Staffin.
—— ? Sedgwickii, *Forbes*: Staffin.
! —— robusta, *Tate*: Loch Bay, Dunvegan.
! Corbula MacNeilli, *Morris*: Staffin.
! —— hebridica, *Tate*: Loch Bay, Dunvegan.
! Pholadomya acuticostata, *Sow.*: Staffin.
Estheria Murchisonæ, *Jones*: Staffin, Tor-Vaig.
Cyprids &c.
! Hybodus polyprion and fish-scales: Loch Bay, Dunvegan, Vaterstein, North Cliffs, Portree.

2. *Oxford Clay.*

Ammonites cordatus, *Sow.*
—— Eugenii, *D'Orb.*
—— Vernoni, *Phil.?*
——, sp.
! —— Jason, *D'Orb.*: Uig.
! —— Lamberti, *Sow.*: Uig.
Belemnites Owenii, *Pratt*: Uig.
—— sulcatus, *Miller*: Uig.
! Littorina Meriani, *Goldfuss.*: Uig.
Ostrea dilatata, *Sow.*: Uig.
! Avicula inæquivalvis, *Sow.*: Uig.
Cucullæa concinna, *Phill.*: Uig.
! Pecten arcuatus, *Sow.*: Uig.
! Pholadomya Protei, *Ag.*: Uig.
Pinna mitis, *Phillips?*
! Nucula elliptica, *Phil.*: Uig.
——, sp.
! Serpula tetragona, *Sow.*: Uig.
! —— plicatilis, *Goldf.*: Uig.

The species with the sign (!) prefixed are now recorded for the first time.

II. Descriptions of New Species.

Belemnites pectinatus, nov. spec. Pl. XII. fig. 13.

Basal portion of guard only known, compressed, terminating abruptly in a quinquefid apex, transverse section ovate-elliptical, axis central. Two approximate lateral furrows divide the apical part of the guard into two unequal lobes, the larger of which presents three short deep grooves.

Length of guard to apex of phragmocone	2 inches.
Major diameter..	1·1 inch.
Minor diameter	·9 „

Horizon.—Inferior Oolite, zone of *A. Murchisonæ*, south side of Portree Harbour, Skye (*R. T.*).

Belemnites confertus, nov. spec. Pl. XII. fig. 14.

Allied to *B. insculptus*, Phil., having a short, stout, bluntly pointed guard, elliptical in section, axis central. There are two indistinct lateral furrows: the apex is eroded; but there are traces of several short, deep grooves.

Total length	2·1 inches.
Major diameter	1·05 inch.
Minor diameter	·85 „
Length of phragmocone	1·05 „
Major diameter	·5 „
Minor diameter	·4 „

Horizon.—Inferior Oolite, zone of *A. Murchisonæ*, south side of Portree Harbour, Skye (*R. T.*).

NERITINA STAFFINENSIS, Forbes, Quart. Journ. Geol. Soc. vol. vii. t. 5. f. 13. p. 110. Pl. XII. fig. 6.

Shell small, ovate, of a brown horn-colour, spire short but prominent, body-whorl slightly impressed towards the suture, ornamented with close and fine transverse striæ; aperture ovate.

Dimensions.—Length $\frac{4}{20}$ inch, breadth $\frac{3}{20}$ inch.

Horizon.—Infra-Oxfordian Estuarine beds, Staffin (*Forbes, R. T.*); Tor-Vaig, near Portree (*R. T.*); and Loch Bay, Dunvegan (*J. B.*).

Numerous specimens in a state of perfect preservation were obtained from a greenish-coloured sandy marl rock, on the west slope of Tor-Vaig, associated with *Cyrena Brycei* and *Melania? inermis*: many of them have the spires eroded; but all retain coloration. The original description of this species is based upon two badly preserved specimens, which appear to be more or less in the condition of casts; I have therefore amended the description and refigured the species.

NERITINA ARATA, nov. spec. Pl. XII. fig. 7.

A minute hemispherical shell, with a short but conspicuous spire, and an inflated body-whorl ornamented with a few thick transverse costæ.

Dimensions.—Length and breadth about $\frac{1}{10}$ inch.

Horizon.—Infra-Oxfordian beds, Loch Bay, Dunvegan (*J. B.*).

Related to *N. costulata*, Desh., of the Bath Oolite, but separable from it by the number and strength of the costæ, and by the exserted spire.

VALVATA PRÆCURSOR, nov. sp. Pl. XII. fig. 9.

Resembles *V. helicoides,* De Loriol; but the sutures are not so deep, and the whorls do not increase so rapidly. It exhibits much the same variations of form, size of umbilicus, and convexity of base as are presented by that species.

Not one of numerous specimens collected is in a good state of preservation.

Position.—Associated with *Melania inermis, Neritina staffinensis, Mytilus* (cf.) *lithodomus.* Infra-Oxfordian Estuarine beds over Prince Charles's Cave, Portree (*R. T.*).

MELANIA? INERMIS, nov. spec. Pl. XII. fig. 5.

Shell ventricose, longer than broad, spire very short, composed of very narrow, somewhat convex whorls; body-whorl occupying nearly the whole length of the shell. Aperture very narrow posteriorly, expanding anteriorly; columella callous; outer lip sharp.

Dimensions.—Length $\frac{7}{20}$ inch, breadth $\frac{5}{20}$ inch.

Position.—Infra-Oxfordian Estuarine beds, Tor-Vaig near Portree and Vaterstein (*R. T.*).

The generic position assigned to this shell is doubtfully the true one. The general form suggests an affinity with the *Tornatellidæ*;

indeed the specimens with an eroded spire, which are by far the more numerous, very well agree with *Actæon minimus*, D'Archaic, from the Bath Oolite. Nevertheless the callous columella and subeffuse lip indicate an alliance with the *Melaniadæ*, amongst which the present species recalls many forms of *Melanopsis* and *Ptychostylus*, but differs from the first by its entire lip, and from the second by its non-plicated columella. The genus *Melania*, restricted to the shells with a loop-like aperture, seems to offer the best reception.

Hydrobia caledonica, nov. spec. Pl. XII. fig. 8.

Shell small, cylindrical, attenuated at the apex; whorls 6, gradually enlarging, slightly convex, transversely wrinkled; body-whorl with a submarginal varix; aperture ovate; peristome entire; base imperforate.

Dimensions. Length $\frac{2}{10}$ inch, breadth $\frac{1}{10}$ inch.

Horizon. Infra-Oxfordian estuarine beds, Loch Bay, Dunvegan (*J. B.*).

Paludina scotica, nov. spec. Pl. XII. fig. 3.

Shell black, obtusely ovately turbinated; whorls 8 (?), moderately convex, densely transversely striated; base with a slight umbilical furrow.

Dimensions. Height 1 inch nearly, breadth ·7 inch.

Horizon. Infra-Oxfordian estuarine beds, Loch Bay, Dunvegan (*J. B.*); Vaterstein (*R. T.*).

Leptoxis trochiformis, nov. spec. Pl. XII. fig. 4.

Shell trochiform, few-whorled; base rather flat, imperforate; aperture oblique; whole surface ornamented with graved lines, longitudinally and obliquely transverse.

Position. Infra-Oxfordian estuarine beds, Loch Bay (*J. B.*).

Anomia æstuarina, nov. sp. Pl. XII. fig. 12.

Upper valve hemispherical; umbone central and submarginal; surface densely radiately costate; costæ but slightly elevated, and somewhat undulose.

Position. Infra-Oxfordian estuarine beds, associated with *Mytilus cuneatus* ?, North Cliffs, Portree.

Cyrena (Miodon) brycei, nov. spec. Pl. XII. fig. 1.

Transverse, ovate-trigonal, compressed or subventricose, considerably inequilateral; umbones small, subacute; anteally rounded, short; posteally produced; lunule inconspicuous; ornamented with a few slightly imbricating folds of growth.

Dimensions. Length $\frac{7}{10}$ inch, breadth $\frac{8}{10}$ inch, thickness $\frac{3}{10}$ inch.

Horizon. Infra-Oxfordian estuarine beds, Staffin (*R. T.*); Tor Vaig, near Portree (*R. T.*); and Loch Bay, Dunvegan (*J. B.*).

This species is variable in shape. The cuneate form which I have

selected as the type is connected by numerous specimens with variety *quadrata*, a short, broad, subquadrate shell. The latter is closely related by its outline to *Cyrena Jamesoni* and *C. Cunninghami*, Forbes, but is always slightly pointed behind, and not truncated as in the allied species.

Not having had an opportunity of critically examining the types of Forbes's species from the Staffin estuarine beds, I cannot speak decisively as to the subgeneric position which should be assigned to the shells named by him *Cyrena Jamesoni*, t. v. f. 7 *a*, 7 *b* (? non f. 8 *a*, 8 *b*), and *Cyrena Cunninghami*, t. v. f. 9 *a*, 9 *b*; but I venture to predict that they will be found, on careful study, to be congeneric with the species here described.

Cyrena cucullata, nov. spec. Pl. XII. fig. 10.

Shell thick, trigonal, tumid; umbones prominent, subcentral; lunule distinct; posteally obliquely subtruncated, rounded anteally; surface with many and close lines of growth.

Dimensions. Length 1·2 inch, breadth 1 inch.

Horizon. Infra-Oxfordian estuarine beds, Loch Bay, Dunvegan (*J. B.*).

Potamomya robusta, nov. spec. Pl. XII. fig. 11.

Shell transversely ovate-oblong, subequilateral, rather tumid; anterior margin rounded, posteriorly produced and arched; umbones prominent, curved; surface coarsely wrinkled concentrically with the margin.

Dimensions. Length 1·9 inch, breadth 1·2 inch, thickness ·75 inch.

Horizon. Infra-Oxfordian estuarine beds, Loch Bay, Dunvegan (*J. B.*).

P. robusta is related to *P.*? *Sowerbyi*, Forbes, in its inflated, transversely ovate form, but differs in its more robust habit, produced posterior area, and in its relative narrowness.

Corbula hebridica, nov. spec. Pl. XII. fig. 2.

Shell nearly equivalve, subequilateral, rotund, trapezoidal, gibbous, obliquely carinated; posterior area very narrow and triangular; front margin slightly curved; surface marked with concentric folds, alternately strong and weak.

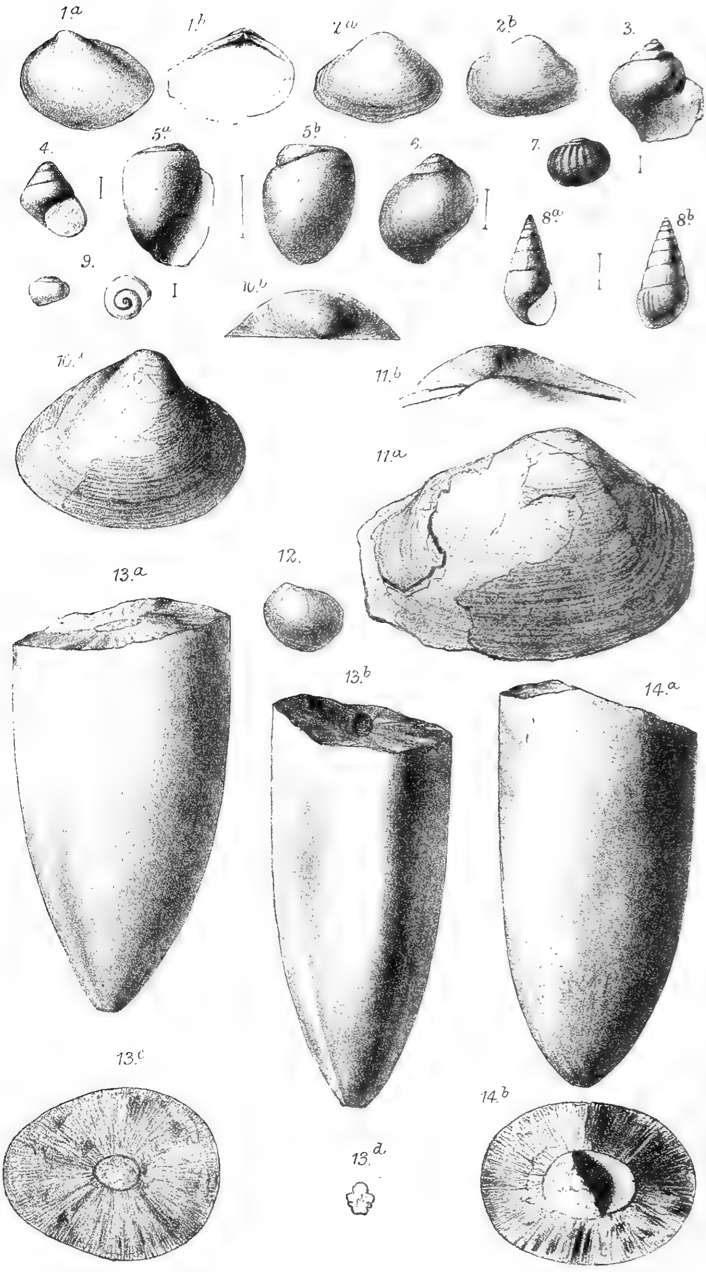
Dimensions. Length $\frac{7}{20}$ inch, breadth $\frac{5}{20}$ inch, thickness $\frac{6}{20}$ inch.

Horizon. Infra-Oxfordian estuarine beds, Loch Bay, Dunvegan (*J. B.*).

This species has the general form of *C. alata*, J. Sow., but is rather more elliptical, has stronger folds, the posterior area is relatively narrower, and the front margin decidedly arched.

Ditrypa circinatum, nov. spec.

Tube about the dimensions of *Dentalium giganteum*, Phil., with which it has been confounded; but the anterior one third forms a semicircle, and the whole presents nodular enlargements at distant, variable intervals; aperture circular, with a bevelled margin.



G.H.Ford & C.L. Griesbach.

Mintern Bros. imp.

HEBRIDEAN FOSSILS.

Horizon. Middle Lias, Raasay, Yorkshire, Gloucestershire. Most abundant in the zone of *Ammonites Jamesoni*, but passing up into that of "*A. spinatus*," Cleveland, Yorkshire.

EXPLANATION OF PLATE XII.

Fig. 1. *Cyrena* (*Miodon*) *Brycei*.
a. Exterior, left valve, nat. size.
b. Interior, left valve.
2*a* & 2*b*. *Corbula hebridica.* Right and left valves, enlarged.
3. *Paludina scotica.* Adult, nat. size.
4. *Leptoxis trochiformis*, enlarged.
5*a* & 5*b*. *Melania? inermis*, slightly enlarged.
6. *Neritina staffinensis*, } enlarged.
7. —— *arata*, }
8*a* & 8*b*. *Hydrobia caledonica*, enlarged.
9. *Valvata præcursor*, enlarged.
10*a* & 10*b*. *Cyrena cucullata*, nat. size.
11*a*. *Potamomya robusta*, nat. size.
11*b*. Umbo.
12. *Anomia æstuarina.*
13. *Belemnites pectinatus.* Figures all of the nat. size.
a. Ventral aspect of guard.
b. Lateral aspect of guard.
c. Transverse section towards apex of phragmacone.
d. Extreme apex.
14*a* & 14*b*. *Belemites confertus.* Lateral aspect of guard, and transverse section.

Discussion.

Mr. Judd pointed out that, contrary to the views of that school of geologists of whom Dr. Macculloch was the leader, and which regarded the geological investigation of Scotland as almost completed, that work was only now being commenced by the application of those principles of Palæontological geology which had been developed in England, and especially fostered by the Geological Society. He congratulated Dr. Bryce on having secured the aid of so experienced a palæontologist as Mr. Tate, and bore witness to the fidelity with which his sections, especially those of the Island of Skye, were described. He also pointed out the importance of this communication as completing the history of a series of sections first so well sketched by Murchison, and in parts described in detail by Geikie, Wright, and Edward Forbes.

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2. Observations *on the* more remarkable Boulders *of the* North-west *of* England *and the* Welsh Borders. By D. Mackintosh, Esq., F.G.S.

[Plate XIII.]

It is presumed that, at a time when so much is said about the conservation of Boulders, a number of personal observations on these interesting objects may not prove unacceptable to the Geological Society.

Westmoreland.—The Shapfell boulders first claim our attention, on

account of their size, the very distinct character of their parent rock, and the fact of their having found their way into Yorkshire over a part of the Pennine Chain, 1500 feet above the sea-level. There is a kind of granite now quarried at Dalbeattie, on the west side of Criffell, which may occasionally be found in drift a great distance to the S.S.E. This granite contains large oblong brown crystals of felspar, and might easily be mistaken for Shapfell granite by one not familiar with the latter *; but in Westmoreland and Yorkshire there would be little chance of such a mistake occurring. The base and sides of Wasdale Crag (from which the granite boulders radiated) are more or less covered with very compact *pinnel* packed full of rounded and glaciated boulders of granite and dark metamorphic felstone. These boulders, however, are seldom very large. On the surface of the pinnel, and more or less associated with a thin covering of red loam and angular *débris*, there are many very large angular or subangular blocks. On walking from Shap to the Shap-summit Granite Works, I saw a block about 12 feet in average diameter, and was credibly informed that there was a block high up on the side of a neighbouring hill which measured $20 \times 15 \times 5$ feet. Split blocks are not uncommon in the district. The number of scattered blocks for many miles to the E., N.E., and N. of Wasdale Crag must have been enormous before their utilization as the foundations of stone walls; and they are still sufficiently numerous to arrest the attention of the railway-traveller. It is well known that there is a very erratic Wasdale-Crag boulder in Darlington; and there is a silly paradoxical saying connected with it—namely, that "it turns round when it strikes one." This saying I have found to be associated with several boulders in other parts of England. The numerous Wasdale-Crag boulders I found around Milnthorpe (and they are well known to be common near Kendal) must have come along a route quite as unexpected as the march over Stainmoor; but the most waywardly erratic of all the boulders from the Shapfell centre of dispersion would appear to be one observed by Mr. Green, F.G.S., in the village of Royston near Barnsley!

Cumberland.—Near Stainton, in the neighbourhood of Penrith, at the base of a hummocky deposit of clay which is overlain by sand and gravel, there is an instance of what may often be seen elsewhere—namely, a number of large, rough, and angular boulders (limestone), which look as if they had been forcibly uprooted from the underlying limestone rock and speedily covered up. On the right-hand side of the road from Penrith to Greystoke, a boulder, $6\frac{1}{2} \times 6 \times 4$ feet, stands on end in a field. It is a very coarse felspathic breccia, some of the included fragments reaching 1 foot in diameter †.

In the interior of the Lake district many boulders cease to be

* The so-called Shapfell boulder, about twelve miles north of Cheltenham, referred to in Professor Ramsay's 'Physical Geology and Geography of Great Britain,' p. 155 (third edition), may possibly be Criffell.

† The main part of this paper has been written for the first time; but several references to boulders already noticed by the author in the 'Geological Magazine' are included for the sake of connexion.

remarkable, on account of their nearness to their parent rocks; but on the plain of Cumberland, and the bordering Carboniferous hills, the boulders are both numerous and interesting. The Bole or Bothel boulder, a short distance from the village of Bothel (near Aspatria) is the most striking I have yet seen. It is a kind of felspathic breccia and conglomerate, which, I think, may have been formed by contemporaneous volcanic and aqueous agency, or by aqueous agency and afterwards metamorphosed. Professor Harkness has described a rock forming part of Binsey Crag, a few miles off, from which the Bothel boulder may have come, though it may have travelled from a greater distance, but not from so great a distance as the neighbouring villagers believe; for some one has put it into their heads that there is no rock like it nearer than Switzerland!

I have elsewhere written on the dispersion of boulders of Criffell granite over the greater part of the plain of Cumberland*. The larger boulders may be best seen on the sea-coast, where the waves have denuded the drift-deposits down to the base of the Lower Boulder-clay. The boulders there, though sometimes thinly scattered, are often in great groups called "scars." These groups may be traced along the eastern coast of the Irish Sea from Maryport to Parkgate. The largest boulders I have seen in Cumberland occur on the coast near Flimby. Two of them are of Criffell granite, one measuring $9 \times 7 \times 3$ feet, the other $8 \times 8 \times 3$. Two are of a linear or semigneissose granite (from the Creetown neighbourhood?); one measures $9 \times 6 \times 3$ feet, the other $8 \times 6 \times 3$.

About St. Bees there are many large syenite boulders from Ennerdale; and near the summit of Dent hill (Skiddaw slate) there is a locally celebrated boulder approaching syenite in its composition, at a height of 1100 feet above the sea-level. It is $8 \times 5 \times 4$ feet, and is called Samson's Cobble, Trysting Stone, or Finger Stone (from the supposed marks upon it of the Devil's fingers). Its transportation, as in the case of many boulders elsewhere, is popularly attributed to Satanic agency. Between Seascale and the neighbourhood of Drigg there are many large boulders on the coast. One of them, of enormous size, which, however, I missed seeing, has a tradition connected with it to the effect that the Devil once tried to throw it from the Cumberland mountains to the Isle of Man, and that it fell down far short of its destination.

Mr. Eccleston, of Carlisle, some time ago discovered a number of Eskdale-granite boulders on the west side of Blackcombe (Skiddaw slate) at a height of at least 1000 feet above the sea. I afterwards examined two groups of these boulders, the principal group being on a plateau on the south side of the upper part of Fossbeck. One boulder measured $8 \times 7 \times 3$ feet, another $6 \times 4 \times 3$ feet, and a third $10 \times 8 \times 4$. They are particularly worthy of notice on account of their great size coupled with their altitude above the sea.

Lancashire.—The most important facts connected with boulders in Furness are, first, the limitation of very large boulders to the *base* of the *pinnel* or Lower Boulder-clay, as in the fine sea-coast section near

* Geological Mag. vol. vii., Dec. 1870.

Baycliff, and, secondly, the occurrence of large boulders, generally angular, in the overlying gravel and sand, as in the section at the Ulverstone Railway Station *. The first fact may be seen exemplified not only in Furness, but all along the coast of the Irish Sea, and, indeed, wherever Lower Boulder-clay or pinnel makes its appearance. The very large boulders (with exceedingly few exceptions) are not distributed through its mass, but occur in the lower part in such a way as to suggest that little or no clay had been accumulated when they were transported. The second fact, namely the occurrence of large boulders in the middle gravel and sand, is characteristic of this formation only in the neighbourhood of hilly districts. The finer gravel and sand of the plains contain no boulders; and this may be explained by the supposition that they were deposited partly while floating ice was limited to the neighbourhood of the mountains, and partly during an intraglacial period when floating ice had everywhere disappeared. At the commencement, or towards the commencement, of the middle drift period, and during the accumulation of the upland representative of the lower part of this drift, namely the angular stony red loam of the mountain-slopes, many large blocks were transported to short distances, and a few probably to great distances from their parent rocks. These blocks are generally angular or subangular, and very little glaciated, while the great boulders, which must have been dispersed before or at the commencement of the Lower Boulder-clay period, are almost invariably more or less rounded and generally well glaciated. In some places, I believe, the two kinds of erratics have become mixed.

On the sea-coast of Morecambe Bay, between Carnforth and Morecambe, many large boulders may be seen where the Lower Boulder-clay makes its appearance. This remark applies to the neighbourhood of Blackpool † and other places further south. A number of very large boulders may be seen in Peel Park, Salford; but I am not aware of the precise positions they occupied when found. Near the entrance to the Liverpool Free Library and Museum there is a boulder of felspathic breccia measuring $4 \times 3 \times 2$ feet, which is said to have been found at a great depth in the Boulder-clay of the neighbourhood. It is intensely glaciated ‡.

* At Carnforth village a deposit of sand contains two enormous limestone boulders, one of them measuring $9\frac{1}{2} \times 9\frac{1}{2} \times 5$ feet. Towards the base of the great gravel- and sand-section at the railway station, there are many small boulders.

† For a detailed account of the Blackpool drifts by the author, see Quart. Journ. Geol. Soc. vol. xxv. p. 407.

‡ I lately examined the wonderful striated pavement of Triassic sandstone, discovered some time ago by Mr. Moreton, F.G.S., near North Hill Street, Prince's Road, Liverpool. The principal or parallel grooves point to N. 35° W.; and a few cross grooves run between N. 38° W. and N. 50° W. On a sandstone surface lately cleared of upper or brick clay (a little north of St. Silas's Church) I found very distinct grooves vanishing *under* and linearly reappearing *from under* scattered portions of a hard crust of arenaceous matter similar to the more gritty parts of the Lower Boulder-clay at Dawpool. Is this crust a remnant of the gritty matter with which the ice ground down and striated the rock-surface beneath and around? Was this striated pavement (which is very flat) formed by an iceberg which, on grounding, generated a degree of heat capable

Cheshire.—I believe there is no county so remarkable for large and far-travelled boulders as Cheshire. So far as I have been able to understand, they are almost invariably found at the base of the Lower Boulder-clay, or where the nearly bare or quite bare rock comes to the surface—in the latter case suggesting that no clay had ever been deposited, or that after its deposition it had been swept away. I believe that nearly all of them were transported from the Lake district and the south of Scotland before or at the commencement of the Lower Boulder-clay period. On the sea-coast between Dawpool and some distance to the S.E. of Parkgate they occur in great numbers. I measured two, of felstone (one of them, I believe, from Wastwater Screes), the diameters of which were $8 \times 6 \times 6$ and $5 \times 4 \times 2$ feet; two of greenstone, $7 \times 5 \times 4$ and $6 \times 4 \times 4$ feet; and two of Criffell granite, $5 \times 3 \times 3$ and $3 \times 2 \times 2$ feet.

Boulders in Clay near Frodsham.—A few weeks ago (October 1872), I was very fortunate in hearing of a new railway-cutting near Frodsham. Though only just excavated, a rain-wash from a thin and irregular covering of upper or brick-clay had so obscured a great thickness of very hard lower clay interstratified with thin layers of sand, that it required some time to make out the true character and age of the deposits. The lower clay is evidently on the same horizon with that at Dawpool *, and is equally fossiliferous. In some places the underlying Triassic shale had been worked up into the clay, and the latter contained several large angular blocks of local sandstone. At the base of the Lower clay, and more or less imbedded in the rubbly shale, there were four very large erratics, all more or less rounded, and two of them polished and striated. Two, consisting of Eskdale granite, were each about $4\frac{3}{4} \times 4 \times 2\frac{1}{2}$ feet in diameter; and two, of Criffell granite, measured $3\frac{1}{2} \times 3\frac{1}{2} \times 1$ and $3 \times 1\frac{1}{2} \times 1\frac{1}{2}$ feet.

Surface-boulders near Overton.—A few miles to the south of this cutting, the east side of Overton hill and the adjacent flat ground are covered with boulders, which, though on the surface, owing to the absence of clay, are, I believe, of the same age as those above-described. One of them (felstone), a little distance below the refreshment-shed, measures $5\frac{1}{2} \times 4 \times 2$ feet. Lower down there are many granite-boulders, one of which measures $4 \times 2 \times 2$ feet.

Boulders of Delamere Forest.—The heights of Delamere forest (among which Overton Hill may be included) would appear to have been in the central part of the great current which transported boulders from the N.N.W. The boulders are generally found on the flanks of the forest plateau, or in hollows between eminences.

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of hardening the gritty matter, and thus preventing its being swept away from the surface of the rock? This striated pavement, in wet weather, is now covered with water.

* See paper on the Dawpool section, Quart. Journ. Geol. Soc. vol. xxviii. The lower clay referred to in this paper is, I believe, a later deposit than the blue clay of the North Welsh coast, Cumberland, &c. The latter is limited to the mountains or their neighbourhood, is made up of very local material, and nowhere contains far-travelled large boulders.

A few yards from Delamere church I saw five boulders, two small and three large. They were found at a lower level by the Rev. Darwin Fox, and removed to a safe resting-place within the sound of the church-bell. One of them, more or less rounded, consisted of Eskdale granite, and measured $5 \times 3\frac{1}{2} \times 3$ feet; another (Eskdale granite) was polished on one side, and measured $3\frac{1}{2} \times 3\frac{1}{2} \times 2$. The third large boulder consisted of Criffell granite, and measured $3\frac{1}{2} \times 3\frac{1}{2} \times 3$ feet. On one side of it there was a groove about 6 inches wide and 2 inches deep, which curved round part of the boulder. A smaller stone lying in the neighbourhood will fit closely on to the top of this larger boulder; and there is a popular belief that when once so fitted it can scarcely be removed again, owing to the power exercised over it by the Evil Spirit. The tradition is, that the boulders were thrown by the Devil from Beeston Castle, and aimed at Eddisbury hill, but fell a mile short of their destination. It is worthy of remark that the popular diabolical theory of the transportation of boulders, in every instance attributes their present position to their having failed in reaching their intended destination. On the western side of Delamere forest, in the village of Barrow, a number of large boulders may be seen; and here the sandstone rock comes to the surface.

Boulders in Chester.—In Chester, for a very long time past, it has been customary to pave the streets with small erratic boulders and pebbles, and to place large boulders against or at the corners of the walls of houses, &c. It has likewise been customary to pave the swampy roads of the vicinity with similar erratics. A large proportion of the smaller, and a few of the larger stones have been gathered from the surface of arable fields or brought from brick-pits. A certain proportion, including the very large boulders, were probably found in digging house-sites. But I have been informed that most of the stones were brought in boats from the beach running along the N.E. side of the estuary of the Dee, where many similar stones may still be seen. Wherever the stones immediately came from, they can nearly all be traced to parent rocks in the Lake district and south of Scotland. In general they are more or less polished and striated, excepting those which have evidently been subjected to recent littoral attrition. The prevailing rock is a hard felstone, varying in structure from flinty to coarse-grained, and in colour from rather dark (like Wastwater Scree rock) to green and grey. Next comes porphyry, then Criffell, Eskdale, and unknown varieties of granite, and fine-grained syenite from Ennerdale and Wastdale. Felspathic breccia is rather common. Among the smaller stones there is a large percentage of Upper Silurian grit and argillite. Greenstone is not absent; but it does not predominate, as at Dawpool, beyond Parkgate. The number of erratics in Chester and the neighbourhood would undoubtedly be sufficient to build a good-sized town. In the village of Farndon, eight miles south of Chester, there are many intensely glaciated boulders, some of them exceeding 2 feet in average diameter. It would appear that in this neighbourhood they were formerly prevalent in the fields, either on the

surface or slightly imbedded. A farmer told me that many had been removed from the fields by means of a coupling-chain and three or more horses, and that some very large ones had been buried beneath the reach of the plough.

In many villages in Cheshire and elsewhere boulders have become invested with an additional interest from their having rested for centuries in positions in which they were placed by man. At the corner of a tavern or barn, or at the door of a smithy, successive generations of children have, in playful moments, unwittingly effaced marks which were imprinted by ice before Man became a denizen of the earth, and left fresh scratches and polished surfaces of a kind not difficult to be distinguished by the expert, though sometimes calculated to deceive the tyro.

Boulders at high levels.—Far-travelled boulders at a *great altitude* above the sea are especially worthy of attention. Sir Henry de la Beche long ago stated that there were erratics on the Pennine hills up to 1800 feet above the sea. I see no reason why this should be doubted, though I am not aware of any at a greater height than from 1100 to 1500 feet on Holcombe hill, north of Manchester, in the neighbourhood of Macclesfield, and on Stainmoor. I lately very unexpectedly found a considerable number of boulders, both angular and rounded, but very little glaciated, on the Keuper-sandstone tableland called Raw Head, which is the highest of the Peckforton hills, Cheshire. They may be seen in the neighbourhood of Mr. Gerrard's farmhouse, associated with a thin covering of sandy and pebbly drift, beneath which, in hollows, there is here and there a little clay. They reach an altitude of about 1000 feet above the sea. They consist of Eskdale granite, porphyry, felstone, syenite, a little Criffell granite, &c., and reach $3 \times 3 \times 2$ feet in largest dimensions.

High-level Boulders on the Welsh borders.—In the neighbourhood of Llangollen, resting on Wenlock shale or grit, and Carboniferous limestone or sandstone, there are many igneous boulders. Above Trycarreg farm, S. of Berwyn or Llantysilio station, at the height of at least 1000 feet above the sea, I saw a felstone boulder measuring $8 \times 7 \times 3$ feet; and there are many on the high ridge between Llangollen and Glyn Ceiriog. Some distance N. of Nant-y-du, near a chapel, there is a split felstone block measuring $6 \times 3 \times 3$; and all the way up the Eglwyseg limestone-escarpment igneous boulders may be seen. On the summit of the escarpment, up to a height of at least 1600 feet above the sea, many enormous igneous boulders may be found. So far as I have noticed, they are all felspathic lava (often very compact), or felspathic ashes. They are generally well rounded. When broken they are found to be weathered white to a certain depth; but their surface is dark-coloured, and altogether they form so great a contrast to the limestone blocks in the neighbourhood that they can scarcely fail to arrest the attention of the most careless observer. They sometimes occupy somewhat perched positions; and I saw one beneath which the limestone beds had evidently been crushed. I measured three, one of them $6 \times 3 \times 3$ feet, another $6 \times 4 \times 4$ feet, and a third $7 \times 4 \times 3$ feet. They must have come

from the volcanic districts of Wales; and I believe that a study of the configuration of the ground would render it probable that they came from the Berwyn hills, and not from Cader Idris, the Arans, the upper Conway district, or the Snowdon range. Angular felspathic blocks may be found scattered on Halkin mountain, Flintshire. These may have come from Snowdon.

I have not noticed striæ on any of the large felstone boulders above mentioned; but the extent to which their surface is weathered would have effaced any previous marks of glaciation.

In the large boulders or groups of large boulders mentioned in this paper I have not noticed any agreement as to the position of the glaciated surface, or the direction of the striæ or longitudinal axes.

In concluding this article I would redirect attention to the groups of large boulders between Wolverhampton and Bridgenorth, long ago discovered by Sir Roderick I. Murchison, and elsewhere described by myself*. I believe they include both Eskdale and Criffell granite—the former having travelled about 130 miles, and the latter 170 miles! The Swiss Geological Commission make a wonder of boulders having been transported from the Alps to distances of 120 and 150 miles†. But in England, I believe, we have not only greater wonders connected with the transporting-power of ice, but (taking the East-Anglian and north-west-of-England drifts together) a more varied and complete series of glacial and postglacial deposits than is perhaps to be found in any other part of the world.

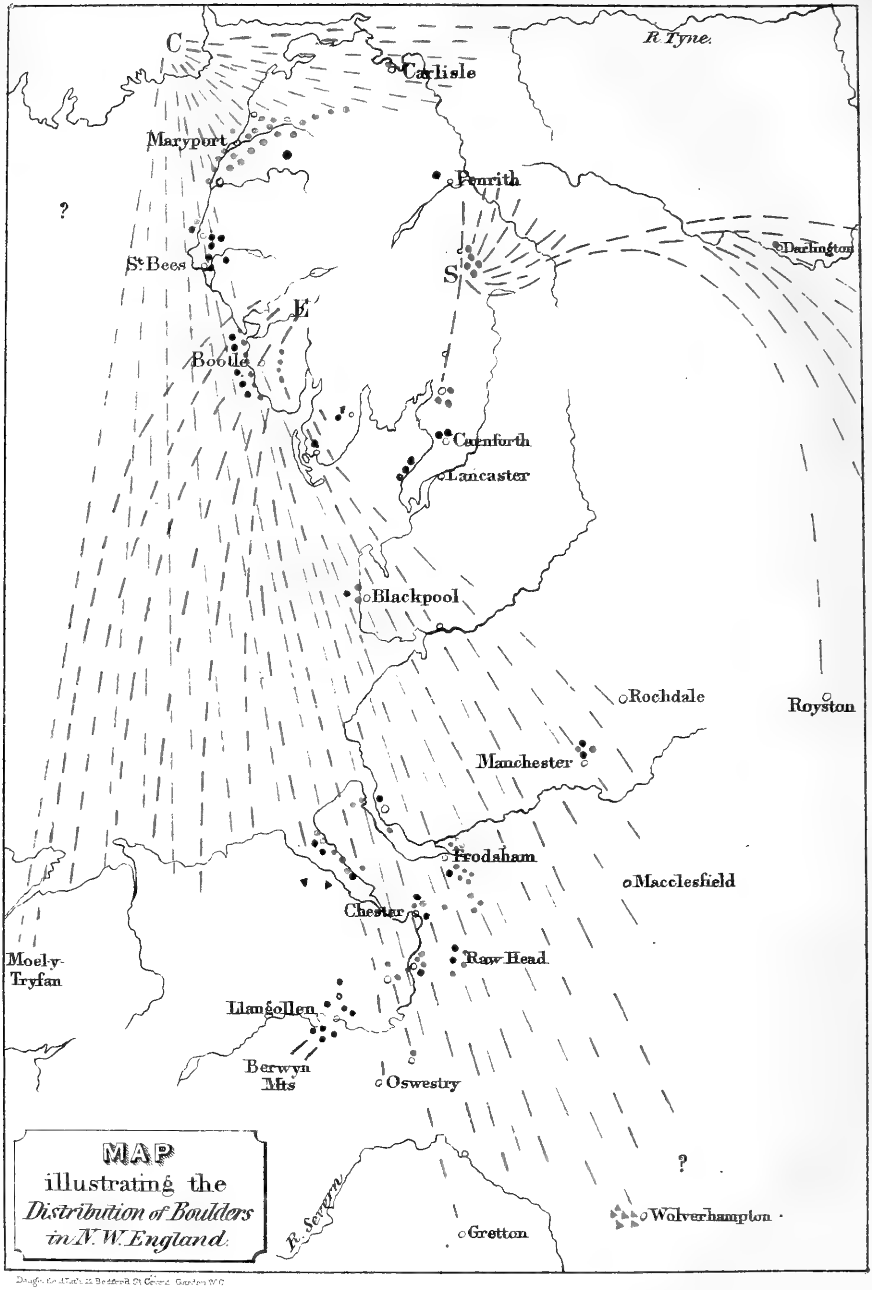
Postcript.

Reexamination of the Trescott Boulders.—A few days ago, I took a journey to Wolverhampton with the view of being able to speak more positively concerning these very far-travelled stones; for when I saw them four and a half years ago, I had not traced the granites found in the drifts of the N. W. of England back to their sources. In the fine rounded gravel west of Wolverhampton (the horizon of which relatively to the drifts further north is still uncertain), I saw many pebbles of Eskdale, but scarcely any of Criffell granite. I was therefore surprised to find that all the large blocks (as well as smaller fragments) of granite around Trescott were Criffell, with the exception of two blocks, which resembled the granite now quarried near Creetown, Kirkcudbrightshire. I saw several hundreds of them, and hammered a great number. Some of the blocks contained a few large crystals of felspar, generally white, but sometimes of a brownish hue—in this respect resembling granite now quarried by the Shap Company near Dalbeattie. In the parishes of Trescott and Trysull they are quite as thickly strewn as on the plain of Cumberland opposite Criffell mountain‡, and actually present a much greater

* Scenery of England and Wales.

† Scheme for the Conservation of Boulders, Proc. Royal Soc. Edin. 1870–71.

‡ The Criffell boulders on the plain of Cumberland are generally more or less rounded, and appear to be associated with the Lower brown clay. I believe they were transported by coast-ice while the sea was comparatively shallow. I have nowhere seen them at a greater height on the hill-sides than 400 feet above the present sea-level.



Griffell Granite ▬ Eskdale Granite ▬ Shapfell Granite ▬
Felspathic and other Rocks ▬ C Griffell. E Eskdale. S Shapfell.
○ Sites of Towns.

proportion of large blocks! The largest I saw during this visit was nearly 5 feet by $3\frac{1}{2} \times 3$, but I was informed that several much larger blocks had been buried at Trescott, and that others might be seen in Trysull parish. I believe that within an area about three miles in diameter there must be many hundreds of granite blocks upwards of 3 feet, and many thousands upwards of $1\frac{1}{2}$ foot in average dimensions. Many of them may be seen by the sides of hedges and lanes; and they form the foundations of many walls. In Cheshire and Lancashire most of the boulders are either rounded or glaciated; but, though at Trescott I saw two or three boulders of a fine-grained rock polished and striated (and during my first visit one block of granite), on this occasion I could detect no striæ on any granite blocks distinct from marks left by the plough and harrow, while very nearly all of them were strikingly angular. I believe that they were not transported along with the rounded and glaciated boulders found in and at the base of the Lower brown clay of more northerly districts, but at a *later* period, and that nothing short of large icebergs at a time when the sea was deep enough to float them without grounding until they struck on an elevated part of the now desiccated sea-bed west of Wolverhampton, will account for the vast array of large blocks which are there crowded within so small a compass*.

EXPLANATION OF MAP, PLATE XIII.

This map is principally intended to show the character, positions, sources, and probable routes of a number of the more remarkable boulders of the N.W. of England and N.E. of Wales. To prevent overcrowding, extensive groups of boulders are frequently represented by a few dots, and many boulders I have not particularly examined are omitted. Only lines pointing to the sources of the granites have been inserted. With the exception of the eastern part of the Shapfell dispersion, the map is founded on the results of personal observation.

Discussion.

Mr. Tiddeman pointed out that, although the *general* course of a boulder might be represented by a straight line drawn from its native rock to its last resting-place, this did not necessarily coincide with the direction of any of the stages of its migration. Besides land-ice, these may have been effected by river-action, and possibly by floating ice during a submergence before the time of the ice-sheet, and certainly by both those agents *after*.

Mr. Hicks called attention to some of the boulders to be seen in the south of Wales, which have been striated by the action of the

* Dr. Buckland in his 'Reliquiæ Diluvianæ' (1824) referred to large boulders between Dudley and Bridgenorth, which are probably a part of the great group under consideration, and regarded them, on the authority of Greenough's Map of England, as Ravenglass (Eskdale) granite. Sir R. I. Murchison, in his 'Silurian System,' mentioned the Trescott and Trysull boulders, and, in his address to the Geological section of the Birmingham meeting of the British Association (1865), correctly assigned to them a Scottish parentage, and spoke of them as having been transported by icebergs. It may be necessary to add that, though the Trescott and Trysull boulders form the most remarkable group, there are many boulders in other parts of Staffordshire.

plough and the harrow, as well as by ice, the marks of which had been almost entirely obliterated by human agency.

Mr. Koch mentioned that in the late floods in Bohemia blocks as large as 6 feet by 4 feet had been transported by the rivers, and their surface had been striated during the process in a manner much like that produced by ice.

Prof. Ramsay pointed out that in some instances the transported blocks had travelled over country higher than the parent beds from which they had been derived, and considered that they afforded some support to the theory of a great and general ice-coating, which was immediately succeeded by a period of great depression below the sea-level, and a subsequent emergence, the whole comprised within one great glacial period. During these oscillations there must of necessity have been a series of dispersions of boulders.

March 12, 1873.

James Geikie, Esq., F.R.S.E., of the Geological Survey of Scotland; William Dugald Campbell, Esq., C.E., Box-Grove Road, Guildford, Surrey; Thomas Jesson, Esq., B.A., Trinity College, Cambridge; and Charles Henry Arbuthnot, Esq., 8 Chapel Street, Grosvenor Square, W., were elected Fellows of the Society.

The following communications were read:—

1. *Note on some* Brachiopoda *collected by* Mr. Judd *from the* Jurassic Deposits *of the* East Coast *of* Scotland. By Thomas Davidson, Esq., F.R.S., F.G.S.

[Printed as an Appendix to Mr. Judd's paper on "The Secondary Rocks of Scotland," at page 196 of the present volume.]

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2. *On* Solfataras *and* Deposits *of* Sulphur *at* Kalamaki, *near the* Isthmus *of* Corinth. By Prof. D. T. Ansted, M.A., F.R.S., F.G.S.

On the eastern side of the important spur of the Alps that stretches down through Albania into Greece and terminates in the southern headland of the Morea, there is a belt of low ground, some of it below the level of the sea, and no part of it at any considerable elevation, that has evidently been subject to volcanic outbursts up to a very recent date. The island of Santorin, lying at some distance to the south east, has very recently been the scene of one of the most important volcanic eruptions of this century; and some islands off the eastern shores of the Morea have been subject to earthquake disturbance, if not to actual volcanic eruption, within the historic period. But there is, I believe, no record of the extension of this belt northwards to the mainland of Greece; nor am I aware of the existence of actual solfataras, either here or in the islands in the Ionian sea, or, indeed, on the eastern side of the Apennines, although

I am aware of several places where volcanic products are found, some on the shores of Italy and others in the Ionian islands.

As affording proof of the fact that there is even now a real, though subdued, volcanic energy in this part of Europe, which may at any time break out afresh in the form of a distinct eruption, and which renders it not at all unlikely that earthquake movements known in the Adriatic and the open Mediterranean may be anticipated in Greece, I have thought that a brief notice of the Solfataras of Kalamaki might be worth recording.

About three miles east of the Isthmus of Corinth a series of cream-coloured and grey gypseous marls flanking white Miocene limestones, which rise to the height of a couple of thousand feet on the northern shore of the Sea of Ægina, is broken by a few narrow rocky gorges and fissures. The dip of the rocks is variable, and the stratification much disturbed. Approaching the rising hills to a level of about 250 feet above the sea, and at a distance from the shore of from half a mile to two miles, these marls are loaded with sulphur; and on entering the gorges it is evident that there has been open communication with some volcanic vent at no distant time.

The principal gorge is narrow and irregular, and it has all the appearance of a natural fissure enlarged by weathering and water-action. Near the entrance on one side there are two considerable lateral fissures within fifty yards of each other, each communicating by a deep crack with the interior, and each consisting of a small cavern lined entirely with crystals of sulphur and other volcanic minerals, and inaccessible, owing to the large body of hot stifling vapour constantly emitted. The temperature of the vapour three feet above the ground, where it can be reached, is about 100° F.; but the floor, consisting chiefly of sulphur, is too hot to permit one to remain long standing even near the entrance. The whole of the walls of this cavity are lined with beautiful crystals, which, however, fall to powder on being removed. Much sulphur exists in fine powdery crystals both on the walls and floor.

A few hundred yards distant, on the same side of the same ravine, and about twenty feet higher, is another similar cavern, with a fissure from which also the vapours are too stifling to admit of the end being reached. The temperature here also is about 100° F. There is a large quantity of pure sulphur in the rocks adjacent.

On the opposite side of the ravine is a third similar fissure, with hot stifling vapours; but the heat is less considerable; and advancing up the ravine more than half a mile from the first solfatara there are numerous places where a sensible heat is felt by the hand on touching the surface, and where hot vapour issues from natural cracks and small fissures in the rock.

The whole of the marls and other rocks in this gorge are loaded with sulphur, and the quantity appears amply sufficient to justify the expectation that it may be worked economically.

Within a distance of about a mile to the east of the ravine just described there are several places on the hill-side where sulphur-bearing rocks are seen wherever the vegetable soil is removed from

the surface; and there are two other valleys each of which has yielded a considerable quantity of sulphur for local purposes.

In each case there are several crevices, with hot vapours issuing from them; and the conditions are precisely similar throughout.

The range of solfataras in this particular district extends for at least a mile, and reaches probably much further in an easterly direction starting from the first ravine. I was informed, though I could not examine the spot, that several miles further almost exactly similar phenomena, on a somewhat less prominent scale, have been recognized. The width of the sulphur-bearing district from north to south is more than half a mile. Thus within a tolerably wide belt of many square miles in total area the ground appears to be penetrated with open crevices communicating below at no great depth with a volcanic vent.

There are unmistakable signs of volcanic action, but no sulphur, to the west of the solfataras, at least as far as the Isthmus. These consist of varieties of lava occasionally intersecting the strata and considerably altering them. On the other side of the Isthmus, in the Gulf of Corinth, the hill on which was the ancient city of Corinth, and which consists of hard limestone and rotten shale, shows the strongest marks of volcanic action. The flat top once covered by the Acropolis is crossed by numerous veins of igneous rock; and there are many yawning fissures passed on the ascent, where basalt is distinctly seen. The adjacent hill is also volcanic.

Thus it appears that lines of volcanic action parallel to the spurs of the Alps (of which Etna and Vesuvius on the western side of the Apennines, and Santorin on the eastern side of the Pindus chain, are the modern vents) have formerly and at no distant period ranged far to the north, and have in each case left behind them clear proof of their existence, not only in masses of sulphur such as are found on the Adriatic coast and in the north of Italy, but in actual solfataras, still recognizable in the mainland of Greece, at a long distance from the nearest modern volcano.

Discussion.

Admiral Spratt mentioned the peninsula of Methana, in the Gulf of Ægina, which within the historical period has risen to a considerable extent (7 stadia according to Strabo), and thus illustrates the influence of modern volcanic action very proximate to the Kalamaki sulphur-springs. It is now nearly 3000 feet high (or over half a mile), or 5 stadia.

Mr. W. W. Smyth wished that the author had drawn a more distinct line between the tertiary beds containing sulphur and those of still more recent origin. The beds near Corinth reminded him much of some in Transylvania; and he was anxious to know whether the direction of the fissures or other phenomena indicated any great disturbance of the strata.

Prof. Ansted, in reply, mentioned that the fissures ran approximately north and south, and were as nearly as possible parallel.

He considered that they were connected with the disturbances which have taken place in comparatively recent times along the eastern coast of the Morea. The sulphur, which usually occurs in small globular masses in gypseous beds, was found in these Solfataras in a crystalline form, and in connexion with the fissures from which the heated gas issues. There was therefore a marked difference in the manner of its occurrence, both in Italy and in Greece. In Greece the sulphur-deposit in nodules is found on the west of the principal chain of mountains, and the crystalline sulphur on the east. In Italy the crystalline sulphur is limited to the vicinity of Vesuvius, and the nodules are abundant both in Sicily and on the east coast of the mainland.

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3. *On the* Origin *of* Clay-Ironstone. By J. Lucas, Esq., F.G.S., of the Geological Survey of England.

A. 1. Clay-ironstone* is an impure carbonate of iron, containing generally from 30 to 33 per cent. of metallic iron mingled with varying proportions of clay, oxide of manganese, lime, and magnesia.

2. When the principal foreign matter in this mineral is of a bituminous or combustible nature the variety thus formed is called "Black band"†. This combustible matter often amounts to 25 or 30 per cent.

3. Sometimes lime so far predominates in Clay-ironstone as to give it the general appearance of a compact limestone, when the presence of iron may be detected by the great weight of the mass, and by the decomposition of the exterior, which turns a dark brown to the depth of a quarter of an inch or more on oxidation.

4. Through the intermediate forms it passes into a pure limestone. Such limestone bands are characterized by being densely compact, very hard, dark-coloured, and by being devoid of organic remains.

B. 1. The foregoing varieties occur throughout the vast thickness of delta-deposits whose remains now constitute the Carboniferous formations. They lie in beds varying in thickness from a fraction of an inch to about 2 feet.

2. When the top of a bed is exposed it is often found to be traversed by a series of cracks, which present the general appearance of a net of very unequal and irregular mesh. These cracks are filled with sediment like that in which the bed of Clay-ironstone lies.

3. Very frequently the beds of all varieties are so irregular as to appear in clean section like a layer of flattened nodules. These irregular layers are always very thin.

4. A glance over the copious details contained in Jukes's "Me-

* Miller's 'Elements of Chemistry,' pt. ii. p. 575, ed. 1864; 'Elements of Geology,' p. 492, 6th ed.; Student's Elements, p. 385; Bristow's 'Glossary of Mineralogy,' p. 87; 'Manual of Geology,' Jukes, p. 356, ed. 1862.

† Miller's 'Elements,' pt. ii. p. 575, ed. 1864; 'Glossary of Mineralogy,' Bristow, p. 44.

moir on the South Staffordshire Coal-field," will show that bands of Clay-ironstone alternate with the same sediments and in the same way as the coals themselves do.

5. Sometimes beds of ironstone rest actually upon beds of coal, as is shown in the following section *:—

No. 1.

	ft.	in.
Black shale	0	2
Clunch	0	10
Batt	0	5
Ironstone	0	2
Coal	1	2
Clunch	3	0
Clunch and Ironstone	4	0
	9	9

"Clunch is a tough clay, breaking into blocks, sometimes rather sandy, generally grey or yellowish"—a description which applies to many seat earths.

"Batt † is a highly carbonaceous shale, commonly very compact and splitting into the finest laminæ, almost invariably black, and often interstratified in layers with the coal"—an impure coal in fact. Both Batt and Clunch appear from these descriptions to be old terrestrial surfaces.

6. That calcareous Clay-ironstone has been formed upon a terrestrial surface is shown by the following section from Millstone-grit shales in Nidderdale, Yorkshire.

No. 2.

	ft.	in.
Black shale	0	1
Nodular limestone	0	5
Coal	0	4
Seat earth	1	10
Grit and shale.		

In the South-Staffordshire coal-field, after the splitting up of the thick coal, fifteen bands of Clay-ironstone occur between the top and bottom coals or limiting horizons, thus pointing to a succession of terrestrial surfaces.

C. 1. On the whole, by comparison with the beds of shale and sandstone, the occurrence of bands of Clay-ironstone, and of ferruginous limestone, in the carboniferous formations above the base of the Millstone-grit is a very exceptional thing.

2. The beds of Clay-ironstone are especially characteristic of those great deltas, though from what follows it will appear that there is no reason *primâ facie* why they should not be found in other deltoid formations as well.

We have thus a general view of the varieties, chemical composition, and mode of occurrence of Clay-ironstones.

* Memoir on South Staffordshire Coal-field, p. 53, 2nd edit. † Ibid. p. 16.

Reverting to A. I, we find the beds so thin, and with so high a percentage of iron, that it appears next to impossible that beds containing it should be thrown down in layers in the midst of sediments almost, and in some cases quite free from it, when we take into consideration the fact that carbonate of iron, which is the salt contained in most ferruginous springs, is rarely present in them in a larger quantity than 1 grain per pint*. Of course I am aware that thick deposits are formed in the open air at the mouths of such springs; but even if carbonate of iron exists in so high a proportion anywhere in estuarine waters, the deposition of it in very thin beds containing 30 to 40 per cent. of metallic iron, appears far less probable than that it should be generally distributed through a greater thickness of mud in less quantity.

For the formation of beds containing a percentage of iron certainly insignificant when compared with that of Clay-ironstones, Prof. Ramsay supposes an inland basin to have been necessary; how much more, then, is it necessary that a bed containing 30 per cent. of iron should have been formed in circumscribed waters?

Again, concerning the varieties of Clay-ironstone which contain a great excess of lime, and of the densely compact thin limestone bands which occur in the millstone-grit series, there can be no doubt that these beds have had a similar origin; for carbonate of lime can rarely be precipitated at the bottom of the sea by chemical action alone†.

The formation of all varieties of Clay-ironstone lying in beds is rendered intelligible by the supposition that they were formed in peaty or non-peaty lagoons on the alluvial flats of the deltas of the Carboniferous formations, according to the predominance or absence of carbonaceous matter in the ironstone. Drained by evaporation and percolation after the subsidence of floods, the stagnant pools occupying these hollows would afford just the circumstances most favourable for the deposition of iron from ferruginous, and lime from calcareous waters, and from the chemical action described by Mr. Hunt. I believe the cracks so often seen in beds of Clay-ironstone to have been formed under these circumstances by the sun when the stagnant pools dried up, as they exactly resemble those formed in the substance of ordinary clay under similar circumstances. The next layer of mud transported into the bed filled them up, so that when seen now they are found to be filled with shale, very often not in the least ferruginous, and quite soft.

This view explains the occurrence of layers of nodules equally well if the surface of the lagoon presented slight undulations, or even in some cases ripple-marks.

It explains also why the beds of Clay-ironstone never run to a greater thickness than about 2 feet, as the lagoons would be necessarily very shallow, in fact nothing but slight hollows in the alluvial flats, sometimes containing a film or bed of peat, sometimes

* Miller's 'Elements of Chemistry,' pt. ii. p. 614, ed. 1864.

† Student's Elements, p. 38.

not, and subject to be overflowed now and then, and to have vegetable matter left in them. The reason why the sediments in which these beds occur are not ferruginous or calcareous to the same extent becomes then equally plain, because the bed of Clay-ironstone formed would sometimes be sufficient to fill the hollow, or a slight subsidence might carry that terrestrial horizon down.

Sometimes these horizons appear to have been spreads of warp, as in the following section copied from the Explanation of Quarter-sheet 93 S.W. In it the black shale is coloured by carbonaceous matter, and in fact is an impure drift coal, and therefore marks a succession of terrestrial surfaces.

No. 3.

	ft.	in.
Ironstone (impure)	0	1
Black shale	0	9
Ironstone	0	$0\frac{1}{2}$
Black shale	0	2
Ironstone	0	1
Black shale	0	8
Ironstone	0	$1\frac{1}{2}$
Black shale	0	1
Ironstone, Top Balls	0	$2\frac{1}{2}$
Black shale	0	6
Ironstone, Middle Balls	0	2
Black shale	0	11
Ironstone, Low Measures	0	$1\frac{1}{2}$
Black shale	1	0

The above section rests upon the terrestrial surface of the Black-Bed Coal.

I can imagine nothing more convincing as to the terrestrial origin of these beds than the above section. By "terrestrial" I mean a surface exposed to the air, but subject to be covered by floods.

The process described by Mr. Hunt might then come into play; in fact I cannot see that it could avoid doing so. Carbonic acid formed in the lagoons from decomposing vegetable matter, meeting with protoxide of iron in solution, would unite with it and form a carbonate of iron; and this, with the mud in the lagoon, would form a clay-ironstone.

I may remark that it cannot be shown that the chemical agents have not formed beds of clay-ironstone when discharged into open waters, that it cannot be proved that they ever did so under those circumstances, and that the above sections do prove that clay-ironstone beds have been formed on terrestrial surfaces.

If the action were possible in open waters, why are the beds not more generally diffused? and why are they so compact and local amongst the beds in which they lie? Surely the red marls of Prof. Ramsay's inland seas should contain them; but they do not.

The above supposition will explain all the varieties of Clay-ironstone lying in beds, of course not those formed by segregation from a state of general dispersion through the sediment in which they lie as concretions. Such concretions may, however, be made

to strengthen the present case, as where the iron was obviously discharged into open waters it was *generally* distributed, and not in local beds.

I believe, then, that every bed of Clay-ironstone marks a terrestrial horizon as much as every coal-bed does, or as every bed of sediment which bears the print of raindrops.

Since the above paper was written I have had the opportunity of witnessing, on a small scale, the operation which I suppose to have taken place on a large one. Between Redcar and Saltburn the shore is guarded by a line of cliffs formed of red Boulder-clay; and between the foot of these and low-water mark there is a broad extent of smooth sand. Several small streams cut through the clay, and at certain times, not being strong enough to cut out a channel through newly laid sand, they sink through it, leaving a film of red mud (peroxide of iron), together with various vegetables brought down by them, and considerable quantities of sea-weed. Some of this mud I took up in a bottle. In a few days, being closely corked, it turned to a dark blue black, and effervesced with nitric acid. Here, then, we have an absolute case of the formation of carbonate of iron under the circumstances named in this paper.

A paper by Mr. James Geikie has also lately come into my hands, in which the following passages occur. "The numerous coal-seams point to a recurrence of a land surface, and the gas-coals and *ironstones* to the former existence of numerous *wide lakes and lagoons*...... Gas-coals are not unfrequently found to pass into common coals, or into black shales, and sometimes into Black-Band ironstones. And this arises from the mode in which these seams were accumulated. Gas-coal has certainly been deposited in water. It contains *fresh-water* or *brackish-water fossils*, and may be traced, as just stated, until it is found to pass into a black argillaceous shale. If we conceive of a more or less wide expanse of fresh water surrounded by broad stretches of densely wooded flat grounds, we shall have the conditions under which the common coals, gas-coals, and ironstones of the limestone series were most probably formed. Over the bed of the lake would gather a slimy vegetable mud, which in some places might be highly impregnated with ferruginous matter. Here and there this slime or black vegetable mud would pass into a dark clay or silt at points where streams entered the lake; while all along the shores, wherever the water shallowed, luxuriant growths of marsh-plants would cluster upon the muddy bottom. Beyond this thick marshy growth, again, there would be the drier land covered with enormous trees and a dense undergrowth of ferns. The plants that grew upon the land would give rise to common coal, the marshy vegetation to splint coal, and the dark vegetable silt to gas-coal, oil-shale, and black-band ironstone; and all these seams would anastomose or pass into each other at certain points. And thus the same mineral seam may be alternately a common, splint, or gas-coal, an oil-shale, or a black-band ironstone, according as the physical conditions varied at the time of its formation. With

regard to Clay-ironstones, I think they are often due to subsequent changes in the strata: the carbonate of iron having been originally more or less diffused through the silt beds, or shales, has segregated in time, so as to form irregular balls or bands." (I have above made a reservation in the case of concretionary balls.) "But the extreme regularity of many of the bands would lead one to infer that these at least were due rather to deposition than to segregation" *.

In the Cleveland district the Oolitic ironstones can sometimes be traced to their natural limits. Their structure changes from an oolitic one to a dense compact Clay-ironstone, first in a number of thin beds, which diminish in number till the whole disappears. Thus a bed of inferior ironstone, known as the "top bed," in some places 30 feet thick, is at one place represented by thirty distinct bands of Clay-ironstone in a thickness of 8 feet, whereas a little further north one single bed, 10 inches thick, of a compact Clay-ironstone, is the sole representative of the 30 feet of loose oolitic ironstone further south. A little further north still there is nothing whatever to represent this bed. These bands appear to me to point to littoral conditions, and to be explained as in the paper.

Note.—An abstract of the above paper, with much additional matter, was published in 'Iron,' April 26, 1873.

Discussion.

Prof. Ansted thought that the explanation offered by the author, though satisfactory for instances of limited thickness and confined area, was not equally applicable to the far larger deposits, such as those in America, extending over hundreds of square miles, and many times as thick as those described. The beds had by some been considered due to segregation subsequently to deposition; but this view also seemed hardly such as could be generally accepted. The deposits of ironstone varied much in character, sometimes consisting of layers of distinct nodules, sometimes of continuous bands. The origin of these two classes appeared to him to have been different; and in some of the Coal-deposits the ironstone bands were present on a more extended scale than seemed consistent with the author's theory.

Prof. Ramsay thought that the paper exhibited considerable ingenuity, and that the examples given by the author were intended by him to be equally applicable to large areas. The estuarine character of much of the Coal-deposits was an acknowledged fact; and the theory proposed by the author was quite in accordance with such a state of things. He did not agree with him that ironstone was never deposited in marine strata, as it occurred in the Yoredale beds and in some Liassic beds. As to the deposits of ironstone in fresh water, he referred to those still taking place in some of the Swedish lakes.

* 'On the Geological Position and Features of the Coal- and Ironstone-bearing Strata of the West of Scotland,' by James Geikie, F.R.S.E., p. 14.

Mr. Forbes, whilst admitting that in many instances Clay-ironstones had been deposited in circumscribed waters or shallow lakes, as is the case with the lake iron-ores in Sweden now actually in process of formation, pointed out that some of the largest Clay-ironstone deposits in England—those of the Yoredale series—contained marine fossils in abundance. On chemical grounds it is not clear in what state of combination the author imagines the iron to have been held in solution previously to being, according to him, converted into carbonate of iron, by meeting with the carbonic acid formed in the lagoons from decomposing vegetable matter; and further, the mere fact that the Saltburn mud effervesced with nitric acid after having been bottled for some days, must not be regarded as necessarily proving the formation of carbonate of iron in it.

Mr. Charlesworth called attention to the nodules of ironstone which were found in the coprolite diggings in Suffolk, as to the origin of which little was known. The banding in the interior of these nodules was posterior to their formation, as was evinced by its following the contours of the exterior, and even of lithodomous borings in them.

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4. *Note in vindication of* Leptophlœum rhombicum *and* Lepidodendron gaspianum. By Principal Dawson, LL.D., F.R.S., F.G.S.

[Abridged.]

The author forwarded to the Society photographs illustrating his species *Leptophlœum rhombicum* and *Lepidodendron gaspianum*, with the view of showing that they are specifically and generically distinct, and also distinct from the plant identified with them by Mr. Carruthers*, and from *Lepidodendron nothum* of Unger †, to which species Mr. Carruthers referred the whole series of specimens, both from Australia and Eastern North America.

Dr. Dawson states that, though he has not seen Unger's specimens, he has carefully studied that author's figures and descriptions of *Lepidodendron nothum*; and in the original description of *L. gaspianum* ‡ he indicated that it is allied to *L. nothum*, although he regarded it as specifically distinct. He considers that *L. nothum* is not at all near to his *Leptophlœum rhombicum*, and that a comparison of Unger's figure or Mr. Carruthers's figure of Mr. Daintree's plant with the photographs of *L. rhombicum* will show that there is not even a generic connexion between them.

To show the want of identity between *Leptophlœum rhombicum* and *Lepidodendron gaspianum*, Dr. Dawson sums up their characters as follows:—

* Quart. Journ. Geol. Soc. vol. xxviii. pp. 351–353.

† Denkschr. Akad. Wiss. Wien, math.-naturw. Cl. vol. xi. (1856) p. 175.

‡ Quart. Journ. Geol. Soc. vol. xv. p. 483.

	LEPIDODENDRON GASPIANUM.	LEPTOPHLŒUM RHOMBICUM.
Stems and branches	Long and slender; areoles elongate-lanceolate.	Short and stout; areoles regularly rhombic or transversely rhombic.
Vascular scars	In middle of areoles, or nearer upper end, according to surface exposed.	Always in middle of areole.
Leaves	Short and much curved outward.	Long and somewhat straight and erect.
Fruit	Small, scaly.	Long, leafy.
Structure	Unknown, but probably allied to Carboniferous *Lepidodendron*.	Known to possess a large *Sternbergia*-pith and to have a very thin cortical layer.

The author reasserts his original opinion of the structure of the leaves and fruit of his *Leptophlœum rhombicum*, which Mr. Carruthers supposed him to have given up from its not appearing in more recent papers.

With respect to the *Sternbergia*-pith of *Leptophlœum*, Dr. Dawson states that he has complete and decorticated specimens of the branches and specimens showing the *Sternbergia*-pith quite exposed. The vascular scars are in the middle of the areoles in both the inner and outer surfaces of the bark, owing to the thinness of the bark (alluded to in the name *Leptophlœum*).

Dr. Dawson remarks that the group to which Presl gave the name of *Bergeria* is Carboniferous, and not Devonian, and that it has no special affinity with *Leptophlœum* or *Lepidophloios*, and he regards Mr. Carruthers's application of that name as objectionable, and tending to produce doubt and confusion.

With regard to the identity of the Australian specimens with those from Canada and Maine, Dr. Dawson does not venture to pronounce an opinion; but he suggests that the Australian plant may be a *Leptophlœum*, although, if Mr. Carruthers's interpretation is correct, he thinks it ought to be placed in a new genus.

DISCUSSION.

Mr. CARRUTHERS observed that, in investigating the plants submitted to him by Mr. Daintree, he could only deal with published observations and drawings in correlating them with known forms. He considered that each systematic worker was at liberty to review the conclusions of previous authors; and if he saw reasons for doing so, to treat their names as synonyms. In *Lepidodendron nothum*, of Unger, the leaves are unknown; but the leaf-scars are rhombic, and the decorticated portion of the stem is marked with oval vascular scars. Principal Dawson, in his *Lepidodendron gaspianum*, figures two kinds of leaves, one short and erect, the other longer and outward-curved; and he showed the external leaf-scars to be rhombic, and the decorticated condition to have oval markings, both exactly as in *L. nothum*, of Unger. No foliage or fruits of

Leptophlœum rhombicum have ever been figured by Principal Dawson, except as a restoration; and as these were entirely omitted in his last work, which includes the results of his researches, Mr. Carruthers had determined its identity with Unger's *L. nothum* from the form of the scars—the only characters given in the published figures, or supplied now by the photographs exhibited. Mr. Daintree's specimens put it beyond all doubt that the supposed *Sternbergia*-pith, on which Principal Dawson apparently founded his genus, was merely the undeveloped portion of the apex of the branch. Mr. Carruthers disputed the characters given as being insufficient to distinguish the plants as species, much less to justify their being placed in different genera. Length or shortness is obviously accidental to the fossil fragments; and their stoutness or slenderness is due to the part of the branch to which they originally belonged. The leaf-scars are not elongate and lanceolate, but rhombic in Principal Dawson's figures of his *L. gaspianum*; and if his drawings are right, the description of the leaves as outward-curved must be wrong. No value can be attached to the position of a vascular bundle which Dr. Dawson says is sometimes in the middle of the leaf-scar in the one plant, and always in the middle in the other, or to the fact (if it be one) that the internal structure in the one is known, and in the other is unknown.

Mr. Etheridge corroborated Mr. Carruthers's views as to the identity of the three forms. He thought that the representations given by Mr. Daintree were superior as regards accuracy to those given by Prof. Dawson. He pointed out that at the end of branches where the scars were crowded together, it was almost impossible to distinguish the arrangement; and he considered that half the species of *Lepidodendra* now in our catalogues would on further examination prove to have had no real existence. We had only to look at a recent tree fern to recognize the difficulty of drawing specific determinations from small or imperfectly preserved specimens.

Mr. Prestwich remarked that the Society were always glad to receive communications from Prof. Dawson, although, of course, there might be a difference of opinion on the subject of such obscure fossils as those under consideration; and he trusted that a question of such importance might be fairly discussed until a definite conclusion was arrived at.

March 26, 1873.

The Rev. Edward Hale, M.A., Assistant-Master at Eton College; William Gibb, Esq., Aberdeen; John Berger Spence, Esq., 75 Mark Lane, E.C.; Frederic W. North, Esq., of Rowley-Hall Colliery, Dudley; John A. Coombs, Esq., C.E., London Gas-Works, Nine Elms, S.W.; and William Kingdon Clifford, Esq., M.A., Fellow of Trinity College, Cambridge, and Professor of Applied Mathematics at University College, London, were elected Fellows of the Society.

The following communications were read:—

1. Synopsis *of the* Younger Formations *of* New Zealand. By Captain F. W. Hutton, F.G.S., of the Geological Survey of New Zealand.

The following synopsis is based on an examination of the Tertiary and Upper Secondary marine fossils in the Colonial Museum at Wellington; but to make it more complete I have added the freshwater coal and lignite formations in the positions I believe them to occupy; this, however, is founded on stratigraphical, and not on palæontological evidence, as also are the remarks on the volcanic rocks.

A short account of the older formations of New Zealand will be found in my report on the Southland District (Geol. Survey of N. Z., Reports of Geological Explorations, 1871–72, p. 96).

Of Tertiary fossils I have been able to determine 375 species of Mollusca, 12 of Brachiopoda, and 18 of Echinodermata, the descriptions of which will, I hope, be published as soon as the plates are prepared. The numbers of the species determined for each formation refer to the Gasteropoda and Lamellibranchiata only.

It must not be inferred from the remarks made in this synopsis that the Tertiary fossils of New Zealand are more nearly related to those of South America than to those of Australia; for as no descriptions of Australian Tertiary fossils have as yet been published, I have not been able to compare them with the New-Zealand fossils.

I am aware that much may be said against employing the European terminology in classifying rocks so far distant as those of New Zealand; but I believe that much more may be said against introducing new names, which are only supposed even to have a temporary value; and no geologist now thinks that a strict synchronism is implied by placing rocks which are far distant from one another in the same formation; every one knows that they are only supposed to be homotaxial with one another. It seems to me also to be merely playing with words to object to the terms Miocene and Eocene, and to substitute for them Middle and Lower Cainozoic; and the latter terms have the great disadvantage of not admitting of any subdivisions without introducing the cumbrous nomenclature of Upper middle, Middle middle, &c., while nothing facilitates the working out of the geology of a country more than subdividing the rocks as much as possible.

CAINOZOIC EPOCH.

Pleistocene Period.

Number of species determined	82
„ of recent species	71
„ passing down into the Whanganui group	48
„ confined to the formation	4
Percentage of recent species	86

Localities.—North Island: Whanganui (Upper Series); Cape Kidnappers (north-west side). South Island: Motanau, Canterbury.

References.—Buchanan, Trans. N. Z. Institute, ii. p. 154 (Sandy Beds).

Remarks.—The pumice plains of the North Island and the shingle deposits of the Canterbury and Southland plains must probably be referred in part to this period and in part to the next.

Pliocene Period.

Newer Pliocene or Whanganui Group.

Number of species determined		89
,,	of recent species	68
,,	passing up into the Pleistocene formation	48
,,	passing down into the Awatere group	29
,,	confined to the group	8
Percentage of recent species		76

Localities.—North Island: Shakespeare's Cliff, Whanganui; Patea. South Island: None known.

References.—Buchanan, Trans. N. Z. Inst. ii. 164 (Blue Clay). Crawford, Trans. N. Z. Inst. ii. 343 (6 in part). Hochstetter, New Zealand, 1867, p. 61 (*c*). Mantell, Quart. Journ. Geol. Soc. iv. 1848, p. 239 (Blue Clay).

Remarks.—This group, which is only found in the north-western part of the Province of Wellington, but extends, perhaps, into Taranaki, consists principally of blue clay. A species of *Natica* is found in it which ranges down to the Ototara group, and which is very like *Mamilla carnatica* of the Cretaceous rocks of India, but intermediate between that shell and *N. mamilla* of Polynesia.

Older Pliocene or Lignite Group.

No marine beds of this age are known in New Zealand.

Localities of Freshwater Beds.—North Island: Plastic clays, with lignite of the Lower Waikato and Drury. South Island: Lacustrine deposits of the Province of Otago, with lignite.

References.—Hector, Quart. Journ. Geol. Soc. 1865, p. 125 (*d*), p. 128 (ii. 1). Hochstetter, New Zealand, 1867, p. 62 (*a* and *b*). Hutton, Geol. Reports, 1871–72, Southland District, p. 112 (Quaternary lignites).

Remarks.—The last great extension of the New-Zealand glaciers must, I think, be referred to this period, as there is no evidence of a colder climate having existed during either the newer Pliocene or the Pleistocene periods; consequently the old moraines, with Moa-bones, of the Canterbury province are probably of this age.

Miocene Period.

Number of species determined		135
,,	of recent species	40
,,	passing up into the Pliocene formation	31
,,	passing down into the Oligocene formation	24
,,	confined to the formation	50
Percentage of recent species		29

Upper Miocene or Awatere Group.

Number of species determined	95
„ of recent species	39
„ passing up into the Whanganui group	29
„ passing down into the Kanieri group	26
„ confined to the group	29
Percentage of recent species	41

Localities.—North Island: White Cliffs of Taranaki; Upper Whanganui river (Paparoa and Parakino). South Island: Port Hills, Nelson (this is the same as "the Cliffs" of Dr. Hochstetter); Conway river; Mount Caverhill, Nelson; Awatere; Motanau, Marlborough; Mount Cookson; Awamoa; Hampden.

References.—Buchanan, Geol. Reports, 1866–67, p. 40 (Blue clay). Crawford, Trans. N. Z. Inst. ii. 343 (5 in part, Sandstones; and 6 in part). Haast, Geol. Reports, 1870–71, p. 25 (10 in part). Hector, Quart. Journ. Geol. Soc. 1865, p. 125 (Moeraki Clay, *c*), p. 128, iv. 2; and Progress Report, 1866–67, p. 2 (*a*). Hochstetter, New Zealand, 1867, p. 61 (*d*, *e* and *g*). Mantell, Quart. Journ. Geol. Soc. 1850, p. 330 (Onekarara clay). Traill, Trans. N. Z. Inst. ii. p. 166 (Blue clay).

Remarks.—This group consists principally of clays, marls, and sandstones; but at Mount Caverhill and Mount Cookson it is calcareous. It occurs only in the southern portions of the North Island, and the northern and western portions of the South Island as far south as Oamaru. *Trigonia semiundulata*, M'Coy, of the Miocene rocks of Australia, is found at Awamoa, and *T. pectinata* at Hampden. The following South-American Miocene fossils also occur in this group, viz. *Natica solida*, *Sigaretus subglobosus*, *Turritella ambulacrum*, and *Limopsis insolita*.

Lower Miocene or Kanieri Group.

Number of species determined	48
„ of recent species	12
„ passing up into the Awatere group	26
„ passing down into the Hawke's-Bay group	13
„ confined to the group	13
Percentage of recent species	25

Localities.—North Island: None known. South Island: Kanieri and Callighan's Creek, Westland, Kokohu; Lyndon; Lower Gorge of the Waipara; Waikari.

References.—Haast, Geol. Reports, 1870–71, p. 25, Amuri District (10 to 13); ibid, p. 5, Waipara District (13 to 15). Hector, Progress Report, 1868-69; p. xii (2. Pliocene).

Remarks.—This group, which is confined to the central portion of the South Island on both sides of the Alps, consists generally of clays and sandstones; but at Kokohu, on the Rangitata river, it is more calcareous. The following South-American Miocene shells are found in it, viz. *Natica solida*, *Turritella ambulacrum*, *Dentalium giganteum*, *Cucullæa alta*, and *Limopsis insolita*.

Oligocene Period.

Number of species determined	69
„ of recent species	15
„ passing up into the Miocene formation	24
„ passing down into the Eocene formation	15
„ confined to the formation	31
Percentage of recent species	21

Upper Oligocene or Hawke's-Bay Group.

Number of species determined	55
„ of recent species	11
„ passing up into the Kanieri group	13
„ passing down into the Waitewata group	11
„ confined to the group	21
Percentage of recent species	20

Localites.—North Island: Napier; "Taipos" on the east coast of Wellington Province; Castle Point; Waitotara. South Island: Hurinui Mound; Trelissick (upper series); east side of Te-Anau Lake.

References.—Crawford, Trans. N. Z. Inst. ii. 343 (5 in part, Limestone). Hector, Geol. Reports, 1870–71, p. 158 (groups 1 and 2); ibid. p. 160 (*a*, *b*, and *c*). Hochstetter, New Zealand, 1867, p. 61 (Hawke's-Bay series, *b*, *f*). Hutton, Geol. Reports, 1871–72, p. 99 (Middle Tertiary, *g* in part).

Remarks.—In the North Island this group is chiefly calcareous, but in the South Island it consists of clays and sandstones. The following South-American Miocene shells occur in it, viz. *Natica solida* and *Cucullæa alta.*

The Tertiary beds of the Chatham Islands (Haast, Trans. N. Z. Inst. i. p. 180, 2, 6 and 7) belong also to this group: in them a well-marked species of *Gryphæa* occurs.

Lower Oligocene or Waitewata Group.

Number of species determined	26
„ of recent species	6
„ passing up into the Hawke's-Bay group	11
„ passing down into the Ototara group	11
„ confined to the group	6
Percentage of recent species	23

Localities.—North Island: Auckland; Kawau; Cape Rodney. South Island: Trelissick (lower series); Waitaki; Limestone of Lake Wakatipu.

References.—Heaphy, Quart. Journ. Geol. Soc. 1860, p. 242 (7). Hector, Geol. Reports, 1868–69, p. 47; Q. J. G. S. 1865, p. 128 (iv. 3). Hochstetter, New Zealand, 1867, p. 60 (Waitewata series, *a*). Hutton, Trans. N. Z. Inst. iii. p. 249 (Waitewata series).

Remarks.—In the North Island this group consists almost entirely

of clays and sandstones, but in the South Island it is often calcareous. It is absent from the southern portion of the North Island and the northern portion of the South Island. A species of *Protocardia*, very like *P. pondicherriensis* from the cretaceous rocks of India, is found at Trelissick. The following South-American Miocene fossils also occur in the group, viz. *Natica solida* and *Dentalium giganteum.*

Eocene Period.

Upper Eocene or Ototara Group.

Number of species determined	43
" of recent species	4
" passing up into the Waitewata group	11
" passing down into the Waipara formation	1
" confined to the group	25
Percentage of recent species	9

Localities.—North Island: Bay of Islands and Whangarei Coal-measures and Limestones; Port Waikato; Raglan; Aotea; Kawhia; Whangape Lake; Lower Waikato; Poverty Bay (lower series); Cape Kidnappers; Cape Turnagain. South Island: Motupipi; Limestones of the Aorere; Tata Island; Takaka; Cape Farewell; Brighton; Kaipuke Cliffs; Blackbirch Creek; Weka Pass (upper series of Mount Brown); Curiosity Shop; Oamaru; Caversham; Saddle Hill?; Winton; Waimea Plains, Southland; Castle Rock; Waiau river; north side of Mount Hamilton.

References.—Crawford, Trans. N. Z. Inst. ii. p. 343 (7?). Haast, Geol. Reports, 1870–71, p. 5, Waipara District (11 and 12, or *f* and *g*, *Cucullœa*-beds); ibid. p. 25, Amuri District (*Scalaria*-beds 12); ibid. 1871–72, Malvern Hill District (7). Hector, Quart. Journ. Geol. Soc. 1865, p. 125 (Oamaru or White Crag, *b*); p. 128, iv. 1); Geol. Reports, 1866–67, p. 17 (Miocene, 3); Progress Report, 1868–69, p. xii (3 and 4); Trans. N. Z. Inst. iv. p. 345 (*a*). Hochstetter, New Zealand, 1867, p. 60 (*b*–*g* and *i*). Hutton, Geol. Reports, 1868-69, p. 7 (lower series *a*); Trans. N. Z. Inst. iii. p. 249 (Papakura and Aotea series); Quart. Journ. Geol. Soc. 1869, p. 13 (Miocene Rocks); Geol. Reports, 1871–72, p. 114 (Bay-of-Islands Coal); ibid. p. 99 (Lower Tertiary, *g* in part). Huxley, Quart. Journ. Geol. Soc. 1859, p. 670. Mantell, Quart. Journ. Geol. Soc. 1848, p. 328 (Ototara Limestone).

Remarks.—This group is widely spread from one end of New Zealand to the other, and occurs on both sides of the Alps. The lower beds are generally marls and sandstones, while the upper are almost always calcareous. Eighteen species of Echinodermata are confined to this group, one of which is a *Caratomus* from the Deans, at Waipara. A species of *Belemnitella* is also found at Saddle Hill, near Dunedin, in rocks referred to this formation by Dr. Hector; but no other fossils have as yet been obtained from the same beds. The following South-American Miocene shells occur in the group, viz. *Natica solida*, *Dentalium giganteum*, and *Cucullœa alta*. The

genus *Struthiolaria* makes its first appearance in this group; but unfortunately the specimens are too imperfect for description of the species.

Lower Eocene, or Brown-coal Group.

No marine beds of this age are found in New Zealand.

Localities for Freshwater formations.—North Island: Coals of Drury, and the Lower Waikato. South Island: Coals of Motupipi; the Lower Buller; Morely Creek; Orepuki; Clutha River; Tokomairiro.

References.—Hector: Progress Report, 1868-69, p. iv (Morely Creek); Parliamentary Papers relating to Coal Mines, 1872, p. 10 (Lower Buller Gorge); ibid. p. 37 (Otago). Hochstetter, New Zealand, 1867, pp. 58, 59. Hutton, Report on Lower Waikato District, 1867; Geol. Reports, 1871–72, Southland District (*f*), p. 99.

Remarks.—The fact that the freshwater Lower Eocene and older Pliocene Coals are brown coals, or lignites, and belong to the hydrous class, while the marine Upper Eocene and Mesozoic Coals are bituminous, and belong to the anhydrous class, is well worthy the notice of chemists.

MESOZOIC EPOCH.

Cretaceous Period.

Danian or Waipara Formation.

Number of species determined	24
,, of recent species	0
,, passing up into the Ototara group	1
,, passing down into the Kawhia beds	1
,, confined to the formation	21

Localities.—North Island: None known.

South Island:—

a. Greymouth Group. Pakawau, or West Whanganui Coal-field; Collingwood or Aorere Coal-field; Mokihinui; Whangapeka Plant-beds; Mount Rochfort Coal-field; Grey Coal-field; Cobden; Mount Hamilton Coal, Southland; Preservation Island; Culverden.

b. Malvern-Hills Group. Boby Creek, Waipara; Weka Pass (lower series); Hororata and Selwyn rivers; Malvern Hills; Shag Point.

c. Amuri Group. Amuri Bluff.

The information is not yet sufficient to say whether any or all of these groups are synchronous or not; but they are closely connected together.

References.—Buchanan, Geol. Reports, 1866–67, p. 38 (Crag Limestone, *a*, *b*). Forbes, Quart. Journ. Geol. Soc. 1855, p. 522 (Preservation Island). Haast, Geol. Reports, 1870–71, p. 5; Waipara (1 to 10, or *b* to *f*); ibid. p. 25, Amuri (3 to 8, 10 A, 10 B, and 10 in part); ibid. 1871–72, Malvern Hills (10 to 16); Parliamentary Papers relating to Coal Mines, 1872, p. 22, Shag Point. Hector, Quart.

Journ. Geol. Soc. 1865, p. 125 (*e*); Progress Report, 1866–67, p. 17 (4, Cretaceo-Tertiary); ibid. 1868–69, p. xii (5, 6 and 7); Geol. Reports, 1870–71, p. 54, Malvern-Hill District, sec. i. *d*, sec. ii. *a* to *e*, sec. iii. *d*; Trans. N. Z. Inst. iv. 345, Cretaceo-Tertiary (*b*, *c*, *d* and *e*); Parliamentary Papers relating to Coal Mines, 1872, p. 9, Grey-river District, p. 11, Mount-Rochfort District, and p. 27, Nelson. Hochstetter, New Zealand, 1867, p. 57 (Jurassic, *a* and *b*); ibid. p. 58 (*c*, *e* and *f*). Hood, Quart. Journ. Geol. Soc. 1870, p. 409. Hutton, Geol. Reports, 1871–72, Southland District, p. 99 (*e*). Owen, Report Brit. Assoc. 1861, Trans. p. 122; Geological Magazine, 1870, p. 49.

Remarks.—This formation occurs on both sides of the Alps in the South Island. The lower beds consist of slates, shales, clays and sandstones, generally with coal, while the upper beds are calcareous. In the North Island it has not yet been recognized. Palæontologically it is more nearly related to the Eocene than to the Jurassic formations; stratigraphically it is almost equally widely separated from both.

This is the Cretaceo-Tertiary formation of Dr. Hector, excluding the Ototara group, which he considers the upper part of it. In his Geological Map of New Zealand he has also included the Jurassic rocks in it. It contains a species of *Myacites*, as well as one of *Dosinia*, two species of *Inoceramus*, one of *Trigonia*, one of *Belemnites*, and one of *Belemnitella*, as well as others of less importance. In it are also found *Lucina americana* of the Cretaceous rocks of South America, as well as *Dentalium majus*, *Cucullæa alta*, and *Waldheimia patagonica* of the Miocene beds of the same country. Among the Brachiopods we find one living species, viz. *Rhynchonella nigricans*. Among the Echinodermata we find a species of *Galerites* (?); but all the rest are Tertiary forms, some of the genera being still living: they are *Macropneustes* (1 sp.), *Kleinia* (1 sp.), *Eupatagus* (1 sp.), *Meoma* (1 sp.), and *Schizaster* (2 sp.). Three species of *Pentacrinus* are also found, one of which occurs also in the Ototara group, as well as *Cucullæa alta*, while another species of *Cucullæa* is found both in this and in the Oligocene formations. On the other hand *Inoceramus Haasti*, from the Jurassic rocks of Kawhia, is also found at Amuri, while in both the Malvern-Hill and Amuri groups the remains of *Plesiosaurus* and *Crocodilus* (?) are found plentifully. These reptilian remains are *in situ*; for shells characteristic of the formation have been found in the concretions with the bones. The plants are chiefly dicotyledons.

Volcanic Rocks.

North Island.—Volcanic action commenced near Auckland during the deposition of the Waitewata group, and from that time to the present it has been more or less continuous in some part or other of the northern, western, or central parts of the island.

References.—Dana, U. S. Exploring Exp. 1849 (Bay of Islands). Davis, Geol. Reports, 1870–71, p. 56 (Thames Gold-fields). Heaphy,

Quart. Journ. Geol. Soc. 1855, p. 31 (Granite &c.); ibid. 1860, p. 242. Hector, Geol. Reports, 1870–71, p. 88 (Cape-Colville district); Trans. N. Z. Inst. iii. p. 278 (White Island). Hochstetter, New Zealand, 1867. Hutton, Quart. Journ. Geol. Soc. 1869, p. 13. Geol. Reports, 1868–69, p. 1 (Great Barrier Island); ibid. p. 15 (Thames Gold-fields); ibid. 1870–71, p. 2 (Coromandel).

South Island.—The Quartzose porphyries of the Malvern Hills and Mount Somers (?) belong to the Waipara formation. No volcanic action appears to have taken place from this time to the close of the Eocene period. During the Oligocene and Miocene periods it recommenced on the east side of the Alps, from Dunedin to the Conway river. Banks's Peninsula appears to belong to the youngest of these volcanic outbursts; but its age has not been ascertained.

References.—Haast, Geol. Reports, 1871–72, Malvern-Hill district. Hector, Quart. Journ. Geol. Soc. 1865, p. 125 (*o*); Geol. Reports, 1870–71, p. 46, Malvern-Hill district. Hutton, Colonial Museum Report, 1870–71, p. 19.

The volcanic rocks of the Chatham Islands belong chiefly to the Hawke's-Bay period; but some may be younger.

Discussion.

Mr. Etheridge remarked on what appeared, from the author's account, to be the great longevity of species in that part of the globe. If the forms had been accurately determined, the percentage that survived from Eocene and Miocene times into the recent period was very far in excess of what survived in Europe. The Belemnites, if found in Europe in Tertiary beds, would have been regarded as undoubtedly derived from some secondary rock. He hoped that researches in the Australian Miocene rocks might throw some light on this subject, but as yet little had been done.

Mr. Blanford stated that in India, so far as was known, there was a marked distinction to be drawn between the Eocene rocks, which were mostly nummulitic, and those of Cretaceous age. In illustration of the occurrence of unlooked-for forms, he mentioned the startling fact that Dr. Waagen had lately found Ammonites associated with Goniatites in Carboniferous rocks.

Prof. T. Rupert Jones recalled the intermingling of Cretaceous and Tertiary genera in the north-western territories of America, and the combination of forms noticed by Mr. Jenkins in Javan strata, where Middle-Tertiary and other shells, which had been regarded as extinct, were found with recent species.

Prof. Ramsay remarked that when in one part of the world there was unconformity of structure and a break in the sequence of the rocks, there must of necessity have been in some other part an undisturbed area in which the different forms of life would be preserved, and where, therefore, it was probable that the representatives of the transitional period between the unconformable rocks would be found.

2. *On the* Tree Ferns *of the* Coal-Measures, *and their* Relations *to other* Living *and* Fossil Forms. By W. Carruthers, Esq., F.R.S., F.G.S.

[Abstract*.]

After referring to the remarkably uniform character of the order of Ferns throughout their whole history on the globe, the author pointed out that there existed in the Coal-Measures two very distinct kinds of fern-stems, each represented by several species. Both of these were very different from the *Chelepteris*-group already described by the author in the Journal of the Society. The first group had a stem-structure like that of living tree ferns. In them the vascular elements of the stem formed a close cylinder round the pith; and the vascular bundles for the leaves were given off from the out-turned edges of the cylinder, where, at regular intervals, corresponding to the position of the leaves, narrow meshes occur for this purpose. To this group were referred the stem described by Lindley and Hutton as *Caulopteris Phillipsii*, and several hitherto undescribed species from Radstock and Newcastle. No materials had yet been detected which could throw any light on the foliage or fruit of these fern-stems. The second group included some stems the casts of which the author had obtained from Radstock, and the root-structures from Halifax. By the help of a fine series of specimens in the collections of the British Museum, he was able to correlate the different parts of these plants. The stems had been described by Corda under the name of *Stemmatopteris*. They differed from the other group chiefly in having the ends of the vascular plates, as seen in the transverse section, turned inwards, and having the bundles of the leaves formed in a complete condition in the axis of the stem. The author showed that the relation of the different parts of the stem in the species of *Caulopteris* was the same as in a first year's dicotyledon; while in the latter group the analogy of the structures was with the monocotyledonous stem. The roots, which surrounded the older portions of the stem, formed the well-known genus *Psaronius*, of Cotta; and as this was the earlier name, it was proposed to retain it for the genus. There was associated with all the fine specimens of this group, which the author had received from J. M'Murtrie, Esq., F.G.S., foliage which had been described as *Cyatheites arborescens*. Although this had not been observed organically connected with the stems, the author adduced several reasons for believing that it belonged to them. If this connexion could be established, it was of the greater importance, as this form was known in fruit; and the fruit established that its affinities were with the living Alsophilas and Cyatheas. Many species of this genus occurred in the continental coal-fields; but the author believed that all the specimens found in England, though differing considerably amongst themselves, belonged to a single species.

* The publication of this paper is postponed.

Discussion.

Prof. Rupert Jones remarked on the combination of organs found in the older forms of vegetable and animal life which were now found separate, and attached to different groups.

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3. *Notes on the* Geology *of* Kazirún, Persia. By A. H. Schindler, Esq.

(Communicated by Joseph Prestwich, Esq., F.R.S., V.P.G.S.)

[Abstract.]

In this paper, which accompanied a series of specimens presented to the Museum of the Society, the author described the section presented by the hills in the neighbourhood of Kazirún. The general surface was described as consisting of nearly unfossiliferous Post-tertiary deposits, immediately beneath which is an unstratified marine deposit containing a great abundance of fossils, among which are species of *Ostrea*, *Pecten*, and *Cidaris* (?). Below this deposit is a succession of strata, repeated several times in the hills; and at the bottom of the series in each case is a bed of gypsum. The spaces between the recurrent series are filled up with conglomerates. Beneath the gypseous series is a formation of compact limestone, which rises to a height of about 1500 feet both north and south of the plain of Kazirún; its beds dip 25°; and their strike is from N.E. to S.W. The author mentioned the occurrence, in a gypsum quarry near Kazirún, of three long cylinders from 6 to 10 feet in diameter, composed of the same material as the surrounding rock. He also stated that he had examined several caverns in the neighbouring mountains, and also the great cave at Shahpoor, but without discovering any organic remains.

Discussion.

Mr. Etheridge was inclined to regard the specimens exhibited as probably of Miocene age. Some of the Pectens resembled those from Malta; and a Crinoid appeared also not to belong to an earlier stage than the Miocene.

Mr. Blanford mentioned that at Shiraz the formation was nummulitic; but along the shores of the Persian Gulf the beds appeared to be of more recent age, containing some existing forms. He thought that possibly the beds described at Kazirún belonged to the gypseous series of Loftus. He did not recognize any of the few fossils exhibited as belonging to the rocks on the shore of the gulf.

April 9, 1873.

Thomas Macdougall Smith, Esq., 1 Chapel Place, Duke Street, Westminster; Archibald Liversidge, Esq., Associate of the Royal School of Mines, Assistant Professor of Chemistry and Lecturer on Geology and Mineralogy at the University of Sidney, N.S.W.; Matthew Robert Bigge, Esq., J.P., of Islip Grange, Thrapston; and John Milne, Esq., 3 Hermitage Villas, Richmond, were elected Fellows of the Society.

The following communications were read:—

1. Lakes *of the* North-eastern Alps, *and their bearing on the* Glacier-erosion Theory. By the Rev. T. G. Bonney, M.A., F.G.S., Fellow and Tutor of St. John's College, Cambridge.

The lakes in many mountain-districts have been attributed to the excavating effect of ice in a period when glaciers extended far beyond their present limits; and this theory has been applied by its author, Professor Ramsay, to several of the best-known lakes of the Western and Central Alps in a very interesting and suggestive paper communicated to the Society, March 5, 1862*. Notwithstanding the skill with which this theory has been advocated by its author, and the support which it has received from many competent judges at home and abroad, I have always felt, in common with not a few who have made Alpine physiography their special study†, that it did not satisfactorily explain all the phenomena; and each visit that I have paid to the Alps has strengthened this opinion.

Professor Ramsay applied his theory chiefly to the lakes of the Western and Central Alps. The following paper attempts to examine those of the North-eastern Alps, especially of the Salzkammergut, the great lake-region of the Eastern district, in order to ascertain whether they also can be attributed to the excavating power of glaciers.

As the general circumstances of climate and orography are fairly similar throughout the great Alpine chain, it may reasonably be expected that any explanation suggested for the lake-basins of one district should apply also to another; and from this we may conclude that, if any explanation which seems possible for one district fail when tested in another, it cannot be the correct one for either. I do not, indeed, concede that the glacial-erosion theory satisfactorily accounts for all the phenomena in the lake-basins of the western and central districts; but as that question has already attracted much attention, I pass it by for the sake of brevity, and am content to rest my case upon the Eastern Alps alone.

In order to demonstrate, as I hope to do, that these East-Alpine lakes cannot be regarded as in any sense primarily due to glacial erosion,

* "On the Glacial Origin of certain Lakes in Switzerland, &c.," by A. C. Ramsay, F.R.S., President of the Geological Society, &c. Quart. Journ. Geol. Soc. vol. xviii. p. 185.

† Among these I may name Sir C. Lyell, M. Favre, Mr. J. Ball, Mr. E. Whymper, Mr. W. Mathews, and the late Sir R. I. Murchison.

I must as briefly as possible sketch out the principal physical features of each one, and in drawing conclusions from these shall lay especial stress upon the two following propositions:—

(1) That, supposing a glacier able to excavate a lake-basin, there must exist above the head of each lake a district capable of producing a considerable glacier.

(2) That under no circumstances can glaciers, especially near their heads, erode considerable precipices or slopes approximately vertical.

The former of these propositions, which amounts to saying that the lake-basins must lie in the lines of what may have formerly been considerable ice-streams (as, for example, do those of Geneva, Como, Maggiore), appears to me as self-evident as saying that a large river cannot exist without a large catchment-basin. The latter will, I think, appear almost as self-evident when the slight flexibility of the ice-stream is considered. The glacier planes, though with varying force; it cannot *dig*.

Best known, and in many respects most remarkable, among these lakes of the North-eastern Alps is the Königsee. It is 1996 feet above the sea, about 2 miles long, and varies in breadth from $\frac{3}{4}$ mile at its upper and lower end to $1\frac{1}{2}$ mile in the middle. The depth is 769 feet*. It occupies a deep valley, almost a gorge, surrounded by a loop-shaped wall of mountains, whose broad undulating top is about 7000 feet above the sea, and is capped by peaks which rise about 1000 feet higher, no one of them surpassing 9000 feet†. The most marked characteristic of this lake is the extreme steepness of its banks, which rise precipitously from the margin, generally for at least 2000 feet—so precipitously, indeed, that the few narrow tracks which lead from the upper pastures to the water's edge would remind the traveller, were it not for the abundance of trees, more of the southern face of the Gemmi than of any other path in the Alps.

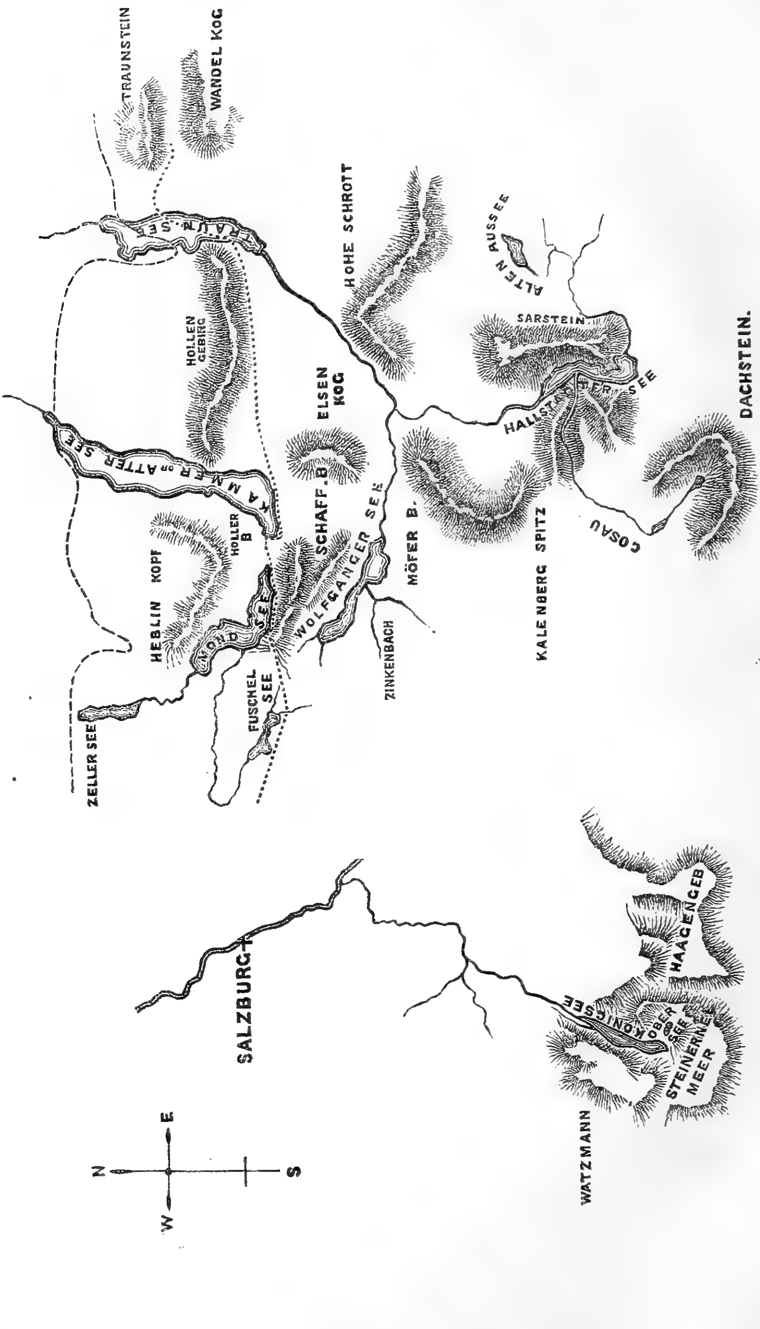
A low bank of débris, about half a mile across, divides the upper end of the Königsee from the Obersee, which is about $1\frac{1}{2}$ mile long and wide, and 155 feet deep. A glance at this from the slopes above the Königsee at once shows its true character. The steep sides of the valley in which the latter lake lies sweep on without interruption from its present head, becoming more and more precipitous, till the glen is terminated by a magnificent wall of cliffs, rising as nearly as possible vertically for at least 1000 feet. It is, in fact, a cirque, similar to those which I have described in a former communication‡. One cascade, of some size, resembling the Staubbach, falls down this gigantic wall, which is streaked again and again by smaller streamlets, generally dry in summer. The barrier between the Obersee and Königsee is formed by two great taluses of débris, which have descended from glens that open on opposite sides of the valley; and beneath the cliffs at the head of the former lake

* These measurements are given on the authority of Dr. H. Wallmann. "Die Seen in der Alpen" (Jahrbuch des osterreichischen Alpen-Vereines, Band iv. p. 1).

† The Watzmann, the highest of the group, is 8988 feet.

‡ Quart. Journ. Geol. Soc. vol. xxvii. p. 312.

Fig. 1.—*Sketch Map, showing the principal lakes near Salzburg.*



The dotted line indicates the northern boundary of the Jurassic, and the broken line that of the Cretaceous rocks; north of this is the Miocene "Wiener Sandstein."

lie other taluses, which have considerably encroached upon it. It is therefore evident that the Königsee formerly extended to the foot of the cirque, and that these deltas, like the level tract at the mouth of the Eisbach, where stands the well-known shooting-lodge of St. Bartolomä, are accumulations of comparatively recent date.

The general direction of the lake is from S. to N.; but at the lower end it turns somewhat to the N.W., becoming shallow, and having its surface broken by at least one island. Owing to the rich herbage and forests which clothe the ground at this end, it was difficult (in the time at my disposal) to determine the precise nature of the barrier which now retains the waters of the Königsee; but I ascertained that it is kept at its *present* level by drift, which, as at the Obersee, has been brought down from two glens opposite one to the other. Here, however, as is shown by the island and by some projecting spurs, the mountains themselves also close on the valley. Hence to Berchtesgaden, a distance of about $3\frac{1}{2}$ miles, there is abundant drift; but though I do not remember to have seen live rock in the river-bed, it must be close to the surface, at any rate, near that village, *i. e.* at a height of about 1740 feet above the sea.

Let us now examine the relation of this remarkable valley to the orography of the neighbourhood*.

At the present day there are only two glaciers in the neighbourhood of the Königsee—a small one between the two peaks of the Watzmann, and the large ice-field of the Uebergossene Alp. Of these, the former lies too far to the N.W. to have occupied the whole basin of the Königsee; the latter belongs to a different drainage-system. Formerly the plateau of the Steinerne Meer must have supported a considerable glacier; but this could hardly have occupied more than a portion of the present lake-basin. Further, it is singular that, if any glacier in this region had been adequate to excavate the Königsee, there is no well-marked trench or trough extending from it to the wide plateau of the Steinerne Meer, where the névé must have been situated. So far from there being a vestige of any such trough, the district between the edge of the plateau and the descent into the trough of the Königsee is peculiarly broken and intricate; in fact, the first valley reached on the descent has no outlet for its waters.

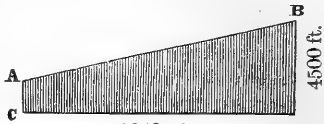
Again, the range connecting the east end of the Steinerne Meer with the Haagen Gebirge and the Kalenberg, which feeds the streamlets descending to the Obersee, is on the whole rather lower than the rest of the chain, while it does not seem in any respect more likely to have produced a great glacier.

Let us now examine the form of the Königsee itself. It is a slightly curved trough, enclosed as described by very steep walls,

* If, after Professor Ramsay's paper, discussing the "fissure" theory is not slaying the slain, one may point out that even this most fissure-like lake cannot in its present form be so explained. Suppose the slope of its sides 60°, and its breadth 1600 yards (both measurements rather favourable to the theory). Its depth should be $800 \tan 60° = 800 (1{\cdot}73) = 1384$ yards, whereas the greatest known depth is less than 260 yards.

which above the Obersee form an almost unbroken precipice at least 1000 feet high. Assuming the glacier to have started at a height of about 6500 feet above the sea, or 4500 feet above the lake, and to have had a course (measured on the flat) of rather more than 2 miles (say 12,500 feet), it then, after descending a bed the average slope of which would be given by the line A B in the diagram, suddenly digs out the cliff A C, after which the average slope of the basin can hardly exceed 3·5 in the 100. Surely a configuration like this is mechanically impossible?

Fig. 2.



If, however, the valley be regarded apart from the lake, it presents no more difficulty to a "rain and river" origin than most others in the Alps, being a gorge-like glen with a cirque at the head formed by the union of several streamlets from various slopes and upland recesses. When, however, we regard the lake, we must account, if possible, for the fact that its bottom at the lowest point is about 500 feet below the true bed of the valley at Berchtesgaden, or possibly even at its north extremity. This we shall attempt to do in a later part of the paper.

The Hallstädter See* is hardly less remarkable than the Königsee for the extreme steepness of its walls. The Sarstein range (6558 feet) hems it in on the east, which presents a steep curtain of pine forest surmounted by a continuous face of limestone rock. On the west the mountains are more broken; but still they rise very abruptly for from 1000 feet to 2000 feet above the lake. This extraordinary trough at the first sight seems not unfavourable to the glacier-erosion hypothesis.

To the S.S.W. is the Dachstein *massif*, which still gives rise to considerable glaciers (9845 feet). The lowest part of the lake-basin is probably not very much less than 600 feet below the rocky bed of the Traun at Lauffen, to which place, about 5 miles distant from the present end, its waters doubtless once extended. A closer examination, however, suggests grave difficulties.

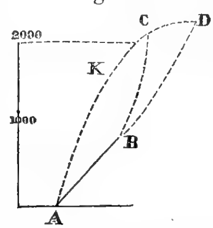
First, the true plan of the lake-basin is not a simple trough pointing at the Dachstein, but a **T**, its head being formed by two well-marked valleys (the Traunthal and the Wildbachthal), each enclosed by precipitous walls, and running E. and W., up which it is evident that the lake once extended. The Traun enters the former arm from the N. by a **V**-shaped glen. The Wildbach torrent rushes into the latter down a magnificent and inaccessible gorge. If, then, the lake is a glacier-basin, one ice-stream must have come down from the E., another from the W., and the two when united have turned to the N. The mountains, however, at the heads of these glens are much lower than the Dachstein, and are not likely to have produced glaciers of exceptional size. If the

* Rather more than 5 miles long and less than $1\frac{1}{2}$ broad, extending from S.E. to N.W. 1769 feet above the sea (v. Buch). Upper part 612, lower 138 feet deep

Karls Eisfeld (the only glacier of any size now left) ever scooped out the Wildbachthal (which is the smaller of the two valleys), it must have followed a very tortuous course, and have left but little trace behind on that part of the channel which it occupied for the longest time.

Again, from the head of the Traunthal and all along the south end of the present lake, a magnificent limestone wall extends without a break, rising to a height which I should estimate (including the slopes of *débris* below) at not less than 2000 feet. The uniformity of this wall (the strata of which run tolerably level) is only interrupted by five cirque-like recesses, the largest of which is exactly at the head of the present lake*. This cirque lies precisely in the line which we might fairly expect the principal glacier of the Dachstein (if it cut out the Hallstadt lake) to have taken. In that case, we must suppose a glacier capable of cutting out a vertical precipice with a steep slope below, together full 2000 feet high. But if this be impossible, the cirque must be either preglacial or post-glacial. If the former, then the valley must have existed nearly in its present condition before the glacier occupied it, and thus the glacier's share in eroding the lake must have been small; for if it had been powerful enough to erode the *basin*, say to its present depth of about 600 feet, surely it must have worn back the great cliff, over whose edge it descended, into a slope of more moderate inclination, as shown in the annexed diagram (fig. 3) by line A B D. If the cirque is postglacial, and the glacier formerly descended some such slope as A K C, then the materials since cut away by the stream (composing the part A B C K) ought to have formed a considerable delta at the head of the lake. Apart, however, from this, I am convinced that the existing talus heaps are a full measure of the total postglacial denudation†. Finally, the Traunthal itself cannot have been cut out by a glacier, because the mountains above the cliffs at its actual head are comparatively low, and slope rather the wrong way, and because the Traun descends through a true river-valley from land of no great elevation.

Fig. 3.



North of the village of Hallstadt, at Gosaumühle, the lake receives the drainage of the western face of the Dachstein from the

* A steep ascent of perhaps 800 feet leads from the lake (by a curious hollow named the Kessel) to a small alp below the cliff. This rises full 1000 feet above the floor of the cirque, now almost wholly covered with débris taluses from the cliff, which is stained by lines of rain-drip, furrowed by three or four watercourses, the largest of these having cut for itself a small *Klamm*.

† If there ever was a moraine in the cirque it is buried beneath the taluses; for the cirque is filling up. All the water which descends into it is swallowed up (as is common in the North-Eastern Alps); so there is little power to remove the débris from the floor. I may add that repeated investigations since those described in my communication (Quart. Journ. Geol. Soc. vol. xxvii. p. 312) have convinced me that the cirques are in their essential features preglacial.

well-known Gosauthal. This also ought formerly to have furnished an ice-stream hardly less important than that which we suppose to have descended the main valley. But the lower part of the Gosauthal is a narrow defile, a V-like valley of river-erosion, about 6 miles long, between the Ramsauer Gebirge to N. (highest summit 6066 feet) and the Plassen to S. (6403 feet). The valley then suddenly expands into an oval fertile and level basin (about 2540 feet above the sea), which has doubtless once been occupied by a lake some 4 miles long. Then it contracts again into a second glen, leading up to the Vorder Gosausee (3051 feet). Above this, higher up the glen, is the Hinter See (4078 feet), a much smaller lake, at the very base of the Dachstein. The latter I was unable to visit. The Vorder See is kept at its present level by a great débris talus, which descends from the cliffs above its left bank. If, then, we suppose that a glacier excavated this, passed down the glen below, and scooped out, chiefly from the soft Gosau (Upper Cretaceous) beds, the basin on which that straggling village now stands, how have the marly (Cretaceous) beds escaped, which are visible at no great height on the left bank of the intervening glen? Again, if the glacier scooped out the Gosau basin, and then, attenuating itself, passed out through the defile below, how was it that this was not cut into a trough? Or if we are to explain the V-shape by subsequent denudation, why is the delta at Gosaumühle so small? Further, if a considerable glacier did descend this valley, and pass over a shoulder of the Gosauhals (a spur of the Kalenberg), it must have thrust the main ice-stream towards the right, and we might expect to find some sign of the increased pressure on that side by a corresponding curvature of the lake-basin. The following extract from my note-book describes the real state of the case:—"Opposite to Gosaumühle the right bank of the lake is an almost level wall of cliff, seamed in many places by small streams, some of which have done no more than smooth out a slight channel."

The above considerations appear to me insuperable difficulties to a theory of glacier-erosion so far as regards the lake of Hallstadt.

Two other small lakes which contribute to the Hallstädter See may here be mentioned. These are the Alt-Aussee* and the Grundlsee†. Both these lie just within glens of a limestone range of moderate elevation. Like the Vorder and Hinter Gosauseen, they are just such as we should most readily concede to glacier-erosionists; but even here the great steepness of the mountains around their heads seemed difficult to reconcile with the theory, and they are certainly maintained at their present level by drift brought down by lateral streams.

The next district which I proceed to examine is the cluster of lakes about the Schaffberg—the Rigi of the Salzkammergut. From this commanding summit (5837 feet) the orography of the neigh-

* About 2 miles long and $\frac{3}{4}$ mile broad, 2247 feet above the sea, 180 feet deep.

† About 1000 yards long and 1300 broad, 2164 feet above the sea, 218 feet deep.

bourhood is readily seen. It is the highest point of a series of limestone ridges, which strike nearly E. and W. (slightly inclining N.N.E. and S.S.W.) and dip sharply towards the S. These parallel ridges, whose summits rise from 5000 feet to 6000 feet, falling rather towards the W., may be traced from the Traunstein, E. of the Traunsee, to the Schober (4366 feet), W. of the Schaffberg, across the massif of the Höllen and Hoch Lecken Gebirge, N. of Ischl. They are composed of Hauptdolomit and Dachsteinkalk, and form the outer part of the Alpine region proper. N. of them, rounded hills, without cliffs and thickly wooded, fall gradually down from elevations of about 3000 feet to the wide expanse of the Bavarian plain. In these* also the same general parallelism may be detected; but their rounded outlines are in marked contrast with the grand northern scarps and steep southern slopes of the limestone ranges. Among the numerous lakes and tarns which are visible from the Schafberg, five are conspicuous both from their size and proximity. Four of these lie at the very base of the mountain; the Fuschelsee and the Wolfganger See on the south, the Mondsee and the Atter See on the north. Somewhat more distant is a smaller lake, called the Zeller See†, which empties itself into the Mondsee.

The Fuschelsee‡ lies in a basin-shaped hollow, the western end being flanked by low hills of rounded outline, which increase in height eastwards. Its size has evidently been greater than at present; for beyond the western extremity is a marshy flat which has been formed by lateral streams. Through this its waters make their way by a circuitous course to the Mondsee. There is also a small delta in the usual position at the eastern end. The Wolfganger See§ is nearly double the size, its breadth and depth being very irregular. This is partly due to a huge delta formed by the Zinkenbach, which extends from the southern side, and almost cuts the lake in two. One sounding, the deepest quoted, is said to be 535 feet; but the general depth is about 250 feet according to Von Falkenstein; and 273 feet for the upper with 230 for the lower part are the measurements assigned to it by Wallmann.

The first glance at the map would lead us to suppose that these two lakes occupied one and the same valley. This, however, is not the case. They are separated by a prolongation of the parallel ridges of the Schaffberg massif, so that orographically the Wolfganger See lies in a synclinal trough which may be traced along a line of lakeless valleys, and is separated from the head of the Fuschelsee by a narrow ridge, which is crossed by the high road at a part 2525 feet above the sea, the central portion of it being a conical peak which rises probably 300 or 400 feet higher.

* They are of Wiener Sandstein (Upper Cretaceous), and are brought against the Jurassic zone by a great northern boundary fault of the Alpine chain.

† About 3 miles long, ¾ wide, 1763 feet above the sea, 118 feet deep.

‡ About 3 miles long, ¾ broad, 2097 feet above the sea, and 249 feet deep (some authorities give the depth twice as much).

§ About 6 miles long, 1¼ broad, 1751 feet above the sea.

If, then, we assume for a moment that these lake-basins were excavated by glaciers, this can only have been effected in one of two ways.

(1) Either a branch of the Hallstadt glacier turned aside at Ischl up the Ach valley, forced its way through the narrow at Pfandl, excavated the Wolfganger See, mounted the steep slope on the west to a height of about 500 feet above the present level of the lake, and then, plunging down the slope on the other side of the ridge, cut out the basin of the Fuschelsee.

(2) Or from the slopes of this ridge and those of the mountains in immediate proximity two glaciers descended, one of which excavated the Fuschel, the other the Wolfganger basin.

With regard to the first of these hypotheses, it is most difficult to understand how the Hallstadt glacier could split asunder and turn the corner (almost a right angle) at Ischl, or how after this it could be forced up an ascent of not less than 1000 feet in not more than 7 miles*, an ascent of about 1 in 35, with nothing in the orography of the neighbourhood to suggest any great additions to the ice-stream. Further, the form of the ridge, sharp, with a well-defined central peak, is wholly unlike what it would have been after the grinding of a great glacier.

As to the second of these hypotheses, one glance at the dividing ridge is enough to show that it never could have given rise to a large glacier on either side.

I believe that no third hypothesis is possible.

We pass on to the lakes on the northern side of the Schaffberg. These three—the Zeller See, Mondsee, and Atter See—are arranged on a U-like curve, the base of which abuts on the precipices of the Schaffberg range. The first†, also called the Irr- or Jungfernsee, lies among low hills of Wiener Sandstein, so low that when regarded from the summit of the Schaffberg it appears to open out on the north to the great plain. Its waters descend a well-marked wide valley, which crosses, roughly speaking, the strike of rolling lines of hills of no great elevation, and enters the Mondsee. This lake‡ now runs up to and curves sharply round to the east beneath the huge precipices forming the northern scarp of the limestone range; but an arm of it doubtless once extended up the valley by which the water comes from the Fuschelsee. In fact, the lower part of the Mondsee may be said to occupy a prolongation of this valley, which is extended to the head of the Atter See§,—the neck of land dividing

* If we assume, as I conclude may fairly be done, the deepest part of the lake to be opposite to the Falkenstein precipice, it would be in 4 miles. This does not adopt the maximum depth quoted above.

† About 3 miles long, $\frac{3}{4}$ broad, 1763 feet above the sea, 118 feet deep.

‡ Rather more than a mile long (?), and about $1\frac{1}{4}$ broad, 1563 feet above the sea, depth 106 feet to 224 feet. "Variable; often as deep at the margin as in the middle."

§ About $12\frac{1}{2}$ miles long, 2 wide, 1544 feet above the sea. Depth variable, greatest at the upper end, being 1163 off Unterach and 1282 near the opposite shore (that is, a few furlongs N. of the middle line of the Mondsee valley), 933 feet opposite to Schwandt, and 311 feet near Buchberg.

these lakes being only a bank of drift, which has mainly descended from the low hills on the north; so that they are practically one lake. It is obvious, then, that these three lakes occupy a connected system of valleys, one parallel with, and two perpendicular to, the general strike of the strata; for the Atter See crosses in reverse order from the base of the limestone escarpment the same rolling lines of hills that are intersected by the valley occupied by the Zeller and upper Mondsee, until they sink down into the great plain. Supposing, then, for a moment this system of valleys traced out by other causes, let us see how far it is possible to explain the lake-basins by glacial erosion.

Excepting that which brings the waters of the Fuschelsee, only one valley of any importance leads to these lakes, viz. that through which a road passes from Ischl to Weissenbach at the S.E. corner of the Atter See. Any one who has travelled along this must admit that it cannot have been traversed by any very large ice-stream, whether this had crossed the low pass from the Traun valley or had descended from the recesses of the Hoch-Lecken and Höllen Gebirge. It is impossible to suppose that glaciers could have been produced among the low hills about the Zeller See, or on the terraced scarp of the Schaffberg, capable of ploughing out this lake-system; can we then adopt the only remaining hypothesis, and suppose that a large glacier descended from the south at right angles to the Wolfganger See, and, after scooping out that lake, passed either on the east or on both sides of the Schaffberg, and ploughed out the troughs above described? The occurrence of the little tarn of the Schwarzen See* on the former of these lines might at first sight seem to favour this hypothesis; but the contours of the neighbouring hills are far from being such as we should expect (being sharp ridges) had they been subjected to such enormous pressure as would be exercised by a glacier capable of grinding out the deep Atter See. No glacier can have passed to the west of the Schaffberg; for the basin of the Wolfganger See is separated from the Mondsee by a ridge (of Dachstein-kalk) which, though of no great height, is as sharp and unworn by ice as the top of the Schaffberg itself. Yet formerly this ridge, when the waters of the lakes stood higher, was the only barrier between them, since a level delta extends up to it on the north from Schörflung on the Mondsee, and on the south it is washed by the Kroten See, a little tarn at the head of what has evidently been an arm of the Wolfganger See, now a shelving expanse of drift.

The remaining lake in this district, the Traunsee† is situated about $9\frac{1}{2}$ miles below Ischl, in the valley of the Traun; but the true head of the lake-basin is nearly 4 miles nearer that town, the intervening space being a delta chiefly formed by affluents from the

* Rather more than a mile long (N.E. to S.W.), 57 yards wide, 168 feet deep, the deepest soundings being in the middle. Height above sea 1880 feet (Ball, Alpine Guide). Wallmann gives it 1159 feet, which is evidently a misprint, a probable correction in the number given (in Vienna feet) would make it 1816—that is, 65 feet above the Wolfganger See.

† Nearly 8 miles long, $1\frac{5}{8}$ wide, 1336 feet above the sea, 626 feet deep.

eastern side. Between Ischl and this head of the lake, the valley of the Traun is comparatively narrow; and though its widening above Eben See is no doubt in some way due to the entrance of the Frauen Weissenbach, there is no appearance of an important glacier having descended that glen; nor, from the elevation of the mountain above it, should we expect to find any. Nor is the rock in this neighbourhood more easily eroded than that further up the stream; for it is all Hauptdolomit, and the head of the present Traunsee is also cut through the same and Dachsteinkalk, the mountains for some distance on either shore rising very precipitously. The lower end of the lake, however, lies among hills corresponding with, and of the same formation (Wiener Sandstein and Tertiary deposits—Marine Schichten) as, the same parts of the Mondsee and Atter See; yet, as in the case of these, there is no very marked expansion of the lake-basin.

Drift evidently retains the waters at their present level; and it forms elevated plateaux, which rise at least 200 feet above the lake, and through which the Traun has cut a deep V-shaped gorge. There are several sections exposed of this drift; it is very distinctly stratified, with false bedding; the pebbles are for the most part limestone (or dolomite), varying in size up to about 5 inches in the longest diameter. There are also occasional blocks (more especially in the upper part), whose solid contents cannot be less than a yard cube. The drift extends over a great distance to the north and west, and is cut out into well-marked terraces and combes, which, it may be remarked, sometimes appear to have but little connexion with the existing drainage-system. Evidently, as is shown by its terraced shores, the Traunsee has once stood at a higher level, as is the case with the other lakes. The valley of the Traun, from the Hallstädter See to Lauffen, and from that place to the former head of the Traunsee, has been filled with Alpine drift, which has been, and in places is still being, cut out into terraces.

Besides the above lakes, there are several smaller, of which I have only had distant views, as well as the extensive Chiemsee*. All these, however, lie among soft Cretaceous or Tertiary rocks, or the drift of the Bavarian plain.

One other lake, not strictly lying within the limits of my district, must however be briefly mentioned in conclusion. This is the Zeller See†, situate in a tributary to the great Pinzgau valley; into this it opens from the N., almost opposite to the mouth of the Fuschthal, which descends from the Glockner group. This lake lies in a well-marked trough-like valley, bounded by summits rising perhaps 5000–6000 feet above the sea. This joins another system of valleys to that of the Pinzgau; two of them run nearly parallel to it. Into the Pinzgau the waters of the lake are discharged over a level plain of drift, while these other valleys

* Nearly 12 miles long and 9 wide, 1638 feet above the sea, and 283 feet deep.

† About 2461 feet above the sea, 363 feet deep. Nearly 4 miles long and $1\frac{1}{2}$ wide.

discharge their waters into the Saale, which escapes northward through a narrow glen in the dolomitic range about the head of the Königsee. Yet the watershed between the Saale and the Zeller See (which enters the Salza) is a low rather irregular plateau, which can hardly rise more than 100 feet at most above the bed of the valley. Difficult as this valley-system is to explain*, it seems impossible to attribute the Zeller See to ice-action. No arm from the Pinzgau, or protrusion of the Fuschthal glacier, could have worked it out; nor, so far as I could see, was there any possibility that a glacier could have come from the north.

The following, then, is the result of my examination of the Salzkammergut and its vicinity:—We have here a district whose lakes, though generally inferior in size to those of Switzerland, are more numerous in proportion to its area. Some of them, to say the least, lie in the neighbourhood of glaciers; others have doubtless been occupied by them. Two of them (the Königsee and the Hallstädter See) differ from all the Swiss lakes in lying practically at the heads of valleys, just where we might expect a glacier-worn basin to exist, if it did at any place; and yet the forms of these two are those which it is most difficult to reconcile with any theory of glacier-erosion. Again others—the Fuschel, Wolfganger, Mond, and Atter Seen—lie where it is almost impossible that any very large ice-stream can have passed, or great pressure been exercised; yet one of these, and that the one most completely protected from glacial action, is the largest and deepest in the whole district, deeper than most of the Swiss lakes†. I think, then, we may safely assert that, when applied to this region, the theory of glacier-erosion fails to account for the phenomena. This being the case, we are led to doubt whether the explanation which seems more specious in the West and Central Alpine regions can, when we regard the general unity of the whole chain of the Alps, be regarded as applicable even there.

Here I must for a moment refer to my previous communication on the formation of cirques, in which I endeavoured to prove that they were in the main preglacial. Further examination of one of those there mentioned, and of several others, has fully confirmed me in this opinion, and convinced me that the excavating agent to which they were assigned (the erosive action of streams) is the true one—convinced me also that all the principal features of the Alps are of earlier date than the glacial epoch.

This being the case, it may be asked "What explanation is to be given of the lake-basins? what agent is capable of excavating these hollows, often more than a thousand feet deep, which indeed sometimes descend to the sea-level? No stream can have done this, no theory of a special subsidence of the area just about the lake can be

* To this subject I hope to return in a future paper.

† The Lake of Geneva is not quite so deep at its deepest part. We may note as a further difficulty that there are no signs of great lakes opposite to the openings of the important rivers of the Salza and the Inn, while the great Chiemsee is connected with a comparatively small valley.

admitted." I can only reply by advancing a theory—a theory I call it, because at present I cannot give a rigid demonstration, indeed, have little hope of ever being able so to do. But, as it seems to me, it can be proved by *reductio ad absurdum*. If a thing can only be black or white, and you prove it cannot be the one, it must be the other. If there are only n possible ways of accounting for a phenomenon, and $\overline{n-1}$ are demonstrated impossible, it follows that the remaining one is correct. This, then, is the method which I chiefly employ here. At the beginning we threw aside, as erroneous, all theories professing to account for lake-basins except two—that which regarded them as results of glacier erosion, and that which considered them produced by inequalities of motion in a vertical direction in the beds of preexisting valleys, which had been produced in the ordinary way by rain and rivers*. We have now rejected the former; the latter only remains. I am, however, bound to show that this is not inconsistent with ascertained facts. This I shall endeavour to do as the conclusion.

Let us consider first the northernmost group of lakes. It is evident that a very old system of valleys exists here—as may be seen from the tongues of *Marine Schichten* (Middle Tertiary) extending southwards in the lower ground into the *Wiener Sandstein* (Cretaceous), showing that certainly the Traunsee, and very probably the Atter See, lie in valleys of early Tertiary age. Yet, though under these circumstances we should expect that the water would pass away northward, we have the stream from the Zeller See descending southward to the Mondsee, and then turning back to pass away through the Atter See; similarly the Waller See (a small lake further to the west) discharges its waters into the Salza. These phenomena would be very well explained by a disturbance of the surface to the extent of a few hundred feet vertical, so as to form one or two rolls parallel to the main chain. The Wolfganger See lies in an old, and possibly to some extent pre-Cretaceous, synclinal with a general E. and W. direction. The western end of the lake, which runs about W.N.W. and E.S.E., is in Dachsteinkalk; but at the eastern end we find the Hauptdolomit appearing, while a little beyond, as well as at Ischl, the Hallstädter Schichten make their appearance, which can hardly be explained without some disturbance. Again, at the northern end of the Hallstädter See, and at the gorge of Lauffen, its natural termination, we have Hauptdolomit, the lake itself lying mainly in Dachsteinkalk. There are indeed no marked signs of disturbance visible in the cliffs, though there are many small flexures in the generally horizontal beds; yet as the general succession of the beds northwards in this region is an ascending one, there appears to be some disturbance here.

But the strongest case of all is at the Königsee. Ascending the southern scarp of the massif out of which it is excavated, we pass

* I wish it to be understood that I do not exclude folds or cracks in the earth's surface, or marine currents as possible *originators* of valleys; but I mean that their present contours are wholly due to meteoric action, except so far as they have been affected by slight upheaval or subsidence.

successively over Werfener Schichten, Hauptdolomit, and Dachsteinkalk, the last being capped on the Steinerne Meer by outliers of beds of Fleckenmergel (Lias). The dip of the strata, as exposed in the cliffs by the side of the lake, is northerly, and we nowhere strike the Werfener Schichten; but on approaching the northern end of the lake, the strata become tolerably horizontal, the Hauptdolomit appears from beneath the Dachsteinkalk, and then the Triassic beds, which at Berchtesgaden are above the level of the river. If, then, any part of this disturbance took place after the erosion of the valley, it would explain the formation of the lake. It is of course obvious that this does not amount to proof of the theory which I have advanced. Proof in a country so disturbed as the Alps cannot be obtained by a traveller; it would require months of careful surveying (wholly out of my power to bestow) to acquire the requisite data: and I doubt much whether they would be acquired then; for flexures and other disturbances of strata are so numerous that I believe it would be quite impossible to give with certainty the date of the last of these, seeing that a movement up and down of a few hundred feet would not very appreciably alter many of the greater curvatures and folds. But I think the above facts show there is nothing unfavourable to the theory; and if the antiquity of the present valley-systems be admitted, and the repeated disturbance of the Alpine chains by earth-movements of greater or less magnitude, it is surely far more probable that, especially in valleys perpendicular to the general strike of the strata, the bed should partake of the flexures due to these movements, should be somewhat depressed at one part and raised at another above the former level, than that it should be moved with perfect regularity over a distance of many miles*. That these disturbances have taken place at earlier dates and to a far greater extent than has been here supposed or required, I trust to be able to show in a future communication†.

* Instances of this unequal motion are described as occurring in historic times, as at Lima (Lyell's 'Principles,' ch. xxv.), also the "Sunk Country" and Run of Cutch.

† One lake-region at least may, I think, be fairly claimed in support of my theory, that of Eastern Palestine. We have there that well-known depression in which the Jordan, after passing through the lakes of Huleh (about sea-level) and Gennesaret (700 (?) below the sea, 156 feet deep, Ritter ii. 237), finally empties itself into the Dead Sea, 1296 feet below the level of the ocean, the greatest depth of this huge brine-pit being about 1300 feet. But from the southern end of the Dead Sea a wide, well-marked trough-like valley passes on between the plateau of the Tih and the mountain-district around Petra, rising gradually to an almost imperceptible watershed near the southern end, whence it descends to the Gulf of Akaba. This watershed is obviously a feature long posterior to the erosion of the valley, which is a true river-valley, and must have once been traversed by the Jordan; perhaps also it sometimes formed a fjord into which the river flowed.

2. *On the* Effects *of* Glacier-Erosion *in* Alpine Valleys. By Signor B. Gastaldi, F.C.G.S.

(Translated from a letter to Sir Charles Lyell, and communicated by permission of Prof. Gastaldi.)

I have all the more pleasure in answering your kind letter, that I have for a long time been waiting for an occasion to write to you, and to send you some geological notes which I have published during the last few years.

For seven years I have been working at a geological map of the Piedmontese Alps, on a scale of $\frac{1}{50000}$; and for the last three years I have been aided in this work by Professor Baretti. The great scale of the maps on which we lay down our work, does not permit us to rapidly survey a very extended area; so that in seven years we have only succeeded in completing the valley of the Orco, comprising the group of the Grand Paradis, the three valleys of Lanzo, including the groups of the Levanna and of Roccia Mellone, and the valley of the Dora Riparia, comprehending the heights of Mont Cenis, the Fréjus, Tabor, Mont Genèvre, Rochesmolles, &c.

Chance led me to pass my holidays in the Alps, where I began to survey geologically the valleys of Lanzo, and ended by taking a fancy for Alpine geology—unhappily a little late; for I am growing old, and the geology of the Alps on a scale of $\frac{1}{50000}$ is rough work, which cannot be done without walks very fatiguing to a man of fifty-five. From the beginning of my work I noticed in the valleys of Lanzo, and at heights between 2000 and 3000 metres, hollows in the form of amphitheatres or great cirques, which have generally a shape like the interior of an armchair, or, more elongated, like a sofa. The back of the armchair is formed of scarped walls cut in the thickness of the mass of the mountain, the two sides by ridges which descend from the mountain; and the part which answers to the seat of the chair, is formed by the inclined slope of the mountain, the surface of which is moutonnée, often striated, and here and there covered by the débris of moraines.

I did not at first attach much importance to this fact, as you yourself and other geologists have admitted that glaciers can, and indeed have deeply excavated the rocks over which they flowed in the heights of the Alps. However, having seen that Mr. Bonney has forestalled me in publishing the same observations (Journal of the Geological Society, 1871) founded on the same facts observed in other Alpine regions, it was my wish to repeat my own observations in the high valley of Susa.

This year in the valley of the Riparia I have found the same facts on a larger scale. First I visited one of these high cirques on the west slope of the Ségures. I found two others in the high valley of Sauze de Césanne, where the upper branch of the Dora Riparia descends. In the first the snows, towards the end of the autumn, have completely disappeared; in the two others we see a glacier reduced to its smallest dimensions. Some of the high cirques or amphitheatres have been cut in limestone, gypsum, or *cargneule,* and others

in calc-schist, and others in much harder rocks, as for example in felspathic, amphibolitic, and chloritic schists, &c. These are narrower and less long, the others vaster and deeper.

For my part I have no doubt that these high cirques are the beds formerly occupied by glaciers but little anterior to the modern period. Glaciers therefore are well able to excavate for themselves deep beds in soft rocks, and also in rocks relatively hard, in high Alpine regions.

Let us now look at the plain, or rather at the mouths of the valleys of the Alps.

In general when entering our Alpine valleys from the plain, their mouths are found to be narrow relatively to their length, their width, and their orographical importance.

Among all our valleys, that of the Dora Baltea (Ivrea and Aosta), that of the Stura (Lanzo Balme), and that of the Riparia (Rivoli-Susa-Césanne), are distinguished in this respect. You know that the valley of the Baltea, which is more than 100 kilometres long, is only a kilometre wide at its opening. The valley of the Stura at its outlet from the Alps at Lanzo opens on the plain by a regular door entirely occupied by the torrent; and the ascending road is obliged to mount on the flanks of the valleys. A geological examination of this locality leaves no doubt that it is the waters of the Stura which have excavated the gorge by which they now discharge themselves on the plain. This work of erosion is still going on; and, in fact, under the bridge we see a gigantic pot-hole, from 6 to 8 metres in diameter, in process of formation. The valley of the Riparia is more than 90 kilometres long from the Col du Grand Miol to the point where it opens on the plain of the Po at St. Ambrogio, and has many lateral valleys—that of Novalesa, which ascends to the plateau of Mont Cenis, that of Bardonèché, comprising the Rochesmolles, the Fréjus, the valley of Méléget and Tabor, the valley of Mont Genèvre, that of Thures, and the long valley of Sauze de Césanne. Yet this valley of the Riparia, so remarkable for its length and interior breadth, is only 800 or 900 metres wide at its exit at St. Ambrogio. What is the cause of this remarkable fact?

The experience which I have acquired in many years' study of the Alps, from Ticino on one side to the Apennines on the other, has convinced me that all the calcareous and felspathic rocks, the granites, porphyries, gneiss, &c., are easily disintegrated by atmospheric action and the power of water, whether liquid or solid, giving rise by decomposition, degradation, and fracture to an enormous quantity of detritus, mostly of very small size. On the contrary, the rocks which best resist these agents are the amphibolites, diorites, syenites, amphibolitic schists, euphotides, serpentines, &c.

These rocks, when present in colossal masses, are, it is true, subject to great landslips, formed of large blocks which do not lose their angularity, nor do they form regular deposits, and therefore never give rise to the formation of good soils; in other words, they permanently resist atmospheric action. For this reason the most difficult summits and the boldest points abruptly rising into the air

are detached from the great Alpine groups. The Matterhorn, the Grivola, the Viso, the needle of Bessans, that of Mondrone, &c. are all or partly composed of these rocks. Mont Blanc and Monte Rosa are colossal masses, while the others are isolated points produced by the fall of their flanks. These dioritic, serpentine, and euphotide rocks are in no wise eruptive. I have followed them for more than 100 kilometres from the valley of the Toce to that of Chisone and the Po; and I have seen that they are disposed in zones, bands, and ribboned layers, which surround the masses of ancient gneiss. Thus the Viso, which, according to M. de Beaumont, is a centre of elevation, is to me only a euphotide layer which has resisted atmospheric degradation, of which the flanks, weatherworn and decayed by rockfalls, now make one of the most beautiful pyramids of our Alps.

These amphibolites, euphotides, and serpentines not only appear in the Alps, but at many other points on the surface of the globe, covering more ancient crystalline rocks, and are in their turn covered by various palæozoic formations. In the Alps of Lombardy and Venetia the zones of serpentine, diorite, and greenstone are found near the centre of the chain running east; but on leaving the St. Gothard they describe a curve and strike towards the south. Thus in Piedmont the diorites, amphibolites, euphotides, and serpentines form the outer band of the Alps towards their base on the border of the plain, and are directly covered by the Pliocene and alluvial strata. The large dioritic band, which in the valley of the Toce is found above and outside the basin of the Lago Maggiore, forms the zone by which the valley of the Baltea debouches at Ivrea; and it is the zone of amphibolite, euphotide, diorite, and serpentine which forms the country at the mouth of the Dora Riparia on its passage to the plain of the Po. This is the reason why the mouths of these two valleys are so narrow. The glaciers of the Adige, of the Ticino, and of the Toce, in debouching into the valley of the Po, have easily eroded the granite (one proof of which is the separation of Mount Orfano from Baveno), mica-schist, limestone, gneiss, &c., and have hollowed large and deep basins. The glaciers of Baltea and Riparia at their opening into the plain met with a large zone of diorite, euphotide, and serpentine, which obliged them to rise, and which resisted their erosive force and consequently the excavation of large and deep basins. I have, however, long been convinced that near Ivrea and Avigliana, in the interior of the two morainic amphitheatres, there was a shallow lake, which is now completely filled, between Avigliana and Rivoli, but which at the Val d'Ivrea still leaves open the two lacustrine basins of Candia and of Viverone. The bottom of these amphitheatres shows no erratic blocks, because they are covered by the alluvium which has filled the lake. The opening of the valley Stura di Lanzo is also barred by a great band of euphotide and serpentine; but here the glacier did not pass out beyond the valley. However, the water that flowed from the end of the glacier (the foot of which I did not find for some kilometres up the valley), impetuously rushing against

the narrow opening fissure in the serpentine, has greatly raised its level, and has formed the magnificent cone of dejection which extends from Lanzo to the Po. (I have described and figured it in the 'Memoria sulla riescavazione dei bacini lacustri:' Milan, 1865.) Thus, the absence of great lacustrine basins at the *débouché* of the Baltea and the Riparia from the Alps proves that glaciers, as well as running water, only wear away with great difficulty amphibolite, euphotide, and serpentines. The presence of great basins at the *débouché* of the valleys of the Ticino, the Adda, and the Adige proves that glaciers easily erode and excavate other rocks.

In Switzerland, at the foot of the Alps, the glaciers of the Rhone and the Rhine met with rocks still less able to resist erosion; and thus, independently of the greater extent of the valleys, they have been able to scoop out more extended and deeper basins.

I do not know the environs of Zurich; but I think that the lignites of Dürnten and Utznach are the remains of preglacial vegetation.

I have given you summarily the reasons which have converted me to Mr. Ramsay's theory, and you will judge them for yourself. I wish I could have given them to you more in detail.

Discussion.

Mr. Drew illustrated the subject by a comparison with the Himalayas, where similar cirques to those in the Alps exist, and are still occupied by glaciers. The arena of the ampitheatres only is occupied by the ice; and the almost vertical slopes are covered with an accumulation of snow, which helps to feed the glaciers. He was not acquainted with any cirque in the Himalayas in which glacial markings are entirely absent. The bottoms of the cirques were not unfrequently lake-basins.

Mr. Blanford instanced a small lake beneath Schneehatten, in Norway, in which a glacier terminated. At the other end the lake was bounded by a hard ridge of rock.

Mr. Koch had studied the effects of glaciers in Switzerland, but had been unable to ascertain the extent of their excavating-power. Where the planing effect of glaciers in ancient times was visible, it appeared to him to have acted in straight, and not in curved lines. He disputed the fact of diorites and serpentines resisting the action of the weather. He had made some experiments on the powers of different rocks to resist the influence of frost and weather, and had been surprised to find how different were the effects under different conditions.

Prof. Ramsay stated that he had not heard any objections now raised to his theories which he had not already answered, or attempted to answer, in print, in the 'Philosophical Magazine' and elsewhere. The strictures of both Sir Roderick Murchison and Sir Charles Lyell were, so far as he remembered, nearly similar to those to which he now had to reply. He pointed out that at the time when Scandinavia and the greater part of the north of Europe, as well as the Alps, were covered with ice, the circumstances were entirely different from what they were at a later time, when there

were merely a few local ice-centres, from which glacier-erosion might radiate. When there was any thing approaching to a general ice-coating, the erosion must have been enormous, especially at spots where there were already preexisting valleys, in which, of course, the ice would be thicker than elsewhere, and where, consequently, its grinding powers would be far greater, and add much to the work of the more ancient rivers. He inquired of Mr. Bonney what must take place at the termination of any glacier. There could be no erosion by the glacier anywhere beyond the point to which it extended; but where it existed some erosion must take place, and a basin of greater or less depth must thus be ground out by the alternating advance and retreat of the glacier. A river flowing out might, it is true, in some cases cut a gorge so as to drain the basin, but this would not prevent a basin being formed. In the western Alps, where the height was greatest, there also were the largest and, in some instances, the deepest lakes; though the size and depth were often connected with the nature of the rock. Some lakes, however, had been partially filled by detritus. As to the cliffs, he perfectly agreed with Mr. Bonney in attributing them to meteoric causes; and in many cases he thought they were of preglacial origin, though subsequently much modified. He repudiated any idea of the larger valleys having, even in glacial times, been always completely filled with ice, and deprecated judging of these questions from diagrams in which the horizontal and vertical scales were different. He repeated that the original large valleys were, in his mind, of great antiquity, but all rather due to erosion in some form or other than to any internal disturbances of the strata. They were therefore to a great extent cut out before the last glacial period. He had been much gratified to find that, after so many years of opposition, the result of Prof. Gastaldi's mapping of the rocks of the country on which he had founded his own opinions, had been to bring the Professor round to the adoption of the same conclusions.

Mr. Blanford added that in tropical mountains (for instance, the Neilgherries in India, and in Abyssinia) he had not been able to trace any ice-action whatever, and there also he had seen no cirques, nor any lake-basins similar to those of Northern Europe. He was therefore compelled to connect both lake-basins and cirques with the existence of glaciers.

Mr. Campbell, of Islay, referring to that portion of Mr. Bonney's paper in which the author alluded to partial subsidence and flexure to account in some degree for the basins of the alpine lakes, described the Thingvalla lake in Iceland. That hollow is over six miles wide, and, for a length of more than twenty miles, is clearly the result of fracture and subsidence of the crust formed upon a great lava flood. Mr. Campbell pointed out that the alpine hollows were not like this Icelandic subsidence, and attributed them to erosion, not to subsidence and flexure. Subsequently the author said that he attributed the valleys to erosion.

The Duke of Argyll thought that Mr. Bonney's paper as to the

formation of these particular lakes had not been answered. It seemed to him that what had been said as to the filling by ice of the valleys with cirques at the sides did not in any way imply that the valleys had been formed by the action of ice. In the case of the Königsee, the vast precipice at the end seemed especially an instance of a cliff that might have existed in preglacial times. He thought that the author's contention that such precipices could not have been formed by the action of glaciers was substantiated. At the same time he would not maintain that glaciers could not excavate basins, but denied their power to excavate deep basins with highly inclined sides. He wished that more attention had been paid to the stratigraphical features of the rocks in which the lakes were excavated. He cited Mr. Kinahan as having stated that the greatest depths of Loch Lomond coincided in position with faults which could be observed in the surrounding country. He differed from Prof. Ramsay as to the preponderance of lakes in regions which have been glaciated, and thought they were more closely connected with the configuration of hilly countries, which was by no means of necessity connected with glacial erosion.

Prof. Ramsay doubted the completeness of Mr. Kinahan's knowledge of the structure of a country which had never been thoroughly mapped. As to cliffs surrounding lakes, he by no means thought that they were now in the same condition as when the glaciers retired. Such cliffs were in fact escarpments working back and undergoing constant change. He could not understand any one acquainted with regions that had been glaciated, as, for instance, the northern half of North America, not connecting the prodigious number of lakes that prevailed with the action of the ice which once covered the country. The longer axis of the lakes in many instances coincided with the general direction of the flow of the ice; and, by itself alone, this circumstance afforded great support to his views.

Mr. Bonney, in reply, pointed out that he had never denied that ice might once have occupied the bottoms of cirques, and even have excavated some of the rock-basins. What he wished to maintain was the necessity of drawing a distinction between primary and secondary causes of the configuration of the country. He thought that the operation of secondary causes had been overrated, and wished that more attention should be paid to the circumstances of the particular lakes to which he had called attention.

April 30, 1873.

Lieut.-Col. J. D. Shakespear, R.A. (retired), 22 Augusta Road, Ramsgate; Richard Clifford Smith, Esq., of Parkfield, Swinton, Manchester; and Rev. Edward S. Dewick, M.A., The College, Eastbourne, Sussex, were elected Fellows of the Society.

The following communications were read:—

1. *On the* PERMIAN BRECCIAS *and* BOULDER-BEDS *of* ARMAGH. By Professor EDWARD HULL, F.R.S., F.G.S., Director of the Geological Survey of Ireland.

THE strata of Permian age hitherto recognized in the north of Ireland have been referred, doubtless correctly, by the authors who have described them, to the upper division of that formation, or the Magnesian-Limestone series (*Zechstein*). The localities where these beds occur are three in number, Cultra on the south side of Belfast Lough *, Tullyconnell Hill near Artrea †, and Templereagh in Co. Tyrone ‡. The strata are for the most part dolomitic; and the fossils they contain are representative of the Magnesian Limestones of the north of England, or of Lancashire.

The beds which I have now to bring before the notice of the Society are considered to be referable, both on stratigraphical and physical grounds, to that Lower Permian series represented by the breccias of Worcestershire and Salop, and by the "brockram" of Cumberland, considered by Professor Ramsay to be an "old Boulder-clay" of Permian age §. In this view I entirely concur, and I may add that the Permian beds of Armagh are not less truly a boulder-formation than those in the English localities above named.

The Permian breccias of Armagh must have been frequently seen by observers, as they are well displayed in quarries; but their true significance has been strangely overlooked. My attention was first called to them in March 1872, by Mr. F. Egan, the Officer of the Geological Survey on duty in that district; and I was immediately struck by their resemblance to my old friends in Worcestershire and Shropshire, especially the beds at Enville and Alberbury. Resting, as they do, on the denuded surface of the Carboniferous Limestone, and surmounted by New Red Sandstone, as proved by wells and excavations in the city of Armagh itself, there was no room for hesitation as regards their age and geological relationship; nevertheless I was gratified to have my own views confirmed by the opinion of the Director-General himself, who, upon visiting the locality in October last in company with Messrs. Egan, Hardman, and myself, at once recognized in these beds the equivalents of the "brockram" of West Cumberland and the boulder-beds of the west of England.

One cause of their having been overlooked by observers seems to be the remarkable fact that the older Boulder-clay is directly overlain by the newer Boulder-clay of the Glacial period; and though the two deposits are sufficiently distinct to enable a practised eye to indicate the line of junction to within an inch, they might easily be mistaken for beds of one formation. The underlying breccia, however, differs from both; and as it consists principally of pieces of limestone

* First described by Dr. James Bryce, Journ. Geol. Soc. Dublin, vol. i. part ii., and afterwards by the same author and Professor King, Brit. Assoc. Rep. 1852, pp. 42 & 53.

† Described by Professor King, Journ. Geol. Soc. Dublin, vol. vii. p. 67.

‡ Sir R. Griffith, Journ. Geol. Soc. Dublin, vol. viii.

§ 'Physical Geology,' 3rd edit. p. 79.

cemented by a sandy calcareous paste, it may have been mistaken for a brecciated form of the Carboniferous Limestone itself.

Description of the beds.—The sections of the Permian breccias and boulder-beds are exposed to view in several old quarries about half a mile to the south-east of Armagh, the quarries themselves having been worked for marble from beds of the Carboniferous Limestone which are in the lower part of that formation. The lowest beds of the Permian, resting directly on the limestone, consist of consolidated breccia of limestone pebbles in a reddish sandy paste, in some cases becoming an evenly bedded calcareous sandstone with pebbles (see figs. 1 and 2). These beds are 10 or 12 feet in thickness, and are over-

Fig. 1.—*Section in Old Quarry near Armagh* (31 feet).

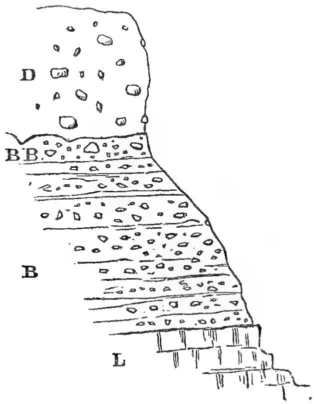
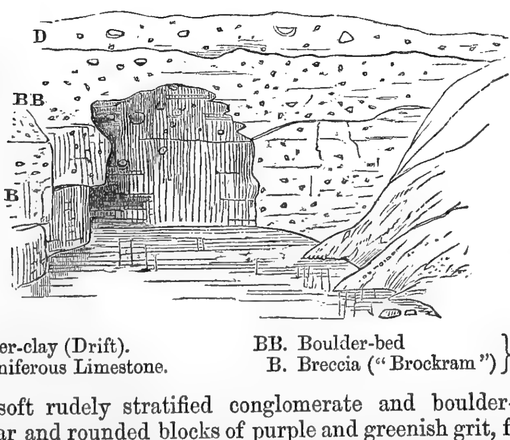


Fig. 2.—*Another Section in Old Quarry near Armagh.*



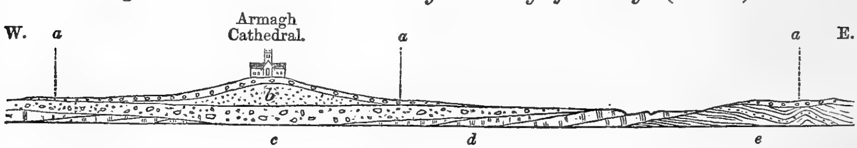
D. Boulder-clay (Drift).
L. Carboniferous Limestone.
BB. Boulder-bed } Permian.
B. Breccia ("Brockram") } Permian.

lain by soft rudely stratified conglomerate and boulder-beds of subangular and rounded blocks of purple and greenish grit, felspathic sandstone, vein quartz, and a few of limestone. In some places the lower calc-breccia ("brockram") graduates upwards into the over-

lying boulder-beds; in other places the latter rests on an eroded surface of the former, and both are overlain by Boulder-clay of the Drift-period (see figs. 1 & 2). The blocks of grit, derived either from the Silurian or Old-Red-Sandstone formations, lying to the northward, are sometimes from 18 inches to 2 feet in diameter, and are not unlike those found in the Boulder-clay of the Glacial period, though we failed to discover any very clear marks of ice-action on their surfaces. It is difficult, however, to conceive how blocks of such size, and so irregular in shape, could have been transported for a distance of 20 or 30 miles (the nearest distance of their original positions), except by the agency of floating ice; and the absence of ice-grooves and scratches on boulders of sandstone which have undergone a certain degree of decomposition from their proximity to the surface, cannot be regarded as a serious objection to the view that the boulders themselves have been carried on ice-rafts.

Position of the Boulder-beds.—On referring to Griffith's Geological Map of Ireland, it will be seen that the city of Armagh stands in proximity to beds but little removed from the base of the Carboniferous Limestone. There are, however, representatives of the New Red Sandstone, which were observed by Mr. Egan in wells and excavations beneath the centre of the city itself. As the Permian beds dip in that direction, they no doubt pass below the New Red Sandstone; so that their geological position is beyond question as regards this formation (see fig. 3).

Fig. 3. *Horizontal Section through the City of Armagh* (1 mile).



a. Drift. *b*. New Red Sandstone, resting on *c*.
c. Permian Boulder-beds. *d*. Carboniferous Limestone.
e. Lower Silurian Rocks.

Their relations to the Carboniferous Limestone can also be clearly determined at the quarries where the boulder-beds themselves are seen. They lie upon beds within 300 or 400 feet of the base of the Carboniferous Limestone, which is worked in numerous quarries in the vicinity. These quarries are celebrated for the number and variety of the fish-remains they have afforded, including some of the type specimens of Agassiz's 'Poissons Fossiles,' now in Lord Enniskillen's collection.

Denudation of the Carboniferous Beds.—As in the north of England, so in the north of Ireland, the amount of denudation which the Carboniferous rocks have undergone before the deposition of the Permian rocks, has been very great. In the case of Armagh, the whole of the middle or "Calp" series, the Upper Limestone, the Yoredale shales, Millstone-grit, and Coal-measures (which are largely developed to the north of Dungannon) have been removed—a total

amount of strata which cannot be estimated at less than 5000 feet in thickness.

This leads me to observe that the Carboniferous rocks of the north-east of Ireland appear to have been subjected to the same system of flexures, accompanied by denudation, which on a former occasion I have shown to have taken place in the case of the same beds in Lancashire at the close of the Carboniferous Period *. The lines of flexure of the Carboniferous rocks of Monaghan, Armagh, and Tyrone † are, in fact, parallel to "the Pendle Axis" of North Lancashire, which ranges in an E.N.E. and W.S.W. direction; and in both cases we find Lower Permian beds resting directly upon those of Lower Carboniferous age, showing a complete parallelism of physical relations. It is, therefore, clear that at the close of the Carboniferous Period the rocks were subjected to an enormous amount of denudation, consequent on the terrestrial movements which ensued, as well in the north of Ireland as in England—an inference which is borne out by the relative positions of the Permian tracts of Cultra and Artrea.

Permian Beds of Benburb.—There is another hitherto unnoticed patch of Lower Permian beds, shown in the banks of the river Blackwater above Benburb, between Armagh and Dungannon. The section is exceedingly obscure, and is to be made out chiefly in the canal-cutting which lies parallel with the river. The beds consist of alternating red marls, purple sandstones, calcareous breccias, and one or two beds of brecciated limestone two or three feet in thickness. The whole of these rest on the upper member of the Carboniferous Limestone, and therefore in a position about 2000 feet higher than in the case of the Armagh boulder-beds. Mr. Baily, F.G.S., has examined a few obscure fossils from the limestone, which he regards as Carboniferous species; but they seem to be not sufficiently perfect for identification; and as I consider the limestone itself to be derivative, and simply a reconstruction of Carboniferous materials, I attach little value to the species of the fossils, even if they were capable of definite identification.

If the Benburb beds had been solitary examples in this district of strata of apparently Permian age, I should have had some hesitation in referring them to that formation; but as they are situated only a few miles distant from the undoubtedly Permian beds of Armagh, I have confidence in the correctness of the identification.

Discussion.

Mr. Prestwich inquired whether in the Permian beds there were no limestone pebbles, such as in all probability would have been striated had they been of glacial origin.

* "On the Relative Ages of the Leading Physical Features and Lines of Elevation of the Carboniferous District of Lancashire and Yorkshire," Quart. Journ. Geol. Soc. vol. xxiv. p. 323.

† The base of the Carboniferous Limestone passing by Clones, Monaghan, and Armagh reappears on the southern shores of Belfast Lough at Cultra, near Holywood, on the same line of upheaval.

Mr. GODWIN-AUSTEN remembered that at the Meeting of the British Association a *Palæoniscus catopterus* and an *Estheria* were produced which were thought to identify the Irish beds with analogous red beds on the other side of the water. He was not prepared to accept the beds to which the name of Permian had been applied as distinct in their origin from those below and above them, and therefore worthy of a distinctive name. The conglomerate bed of the Roth-todt-liegende was only a littoral deposit of that period; and a mere analogy of character did not prove identity of date, as the same parent rocks, when broken up at different times, would yield similar breccias and conglomerates. He regarded the Zechstein period as one of extensive lake-systems, though with occasional incursions of salt water. The Red-Sandstone deposits, as a rule, were, in the west, formed in fresh water; and in more eastern districts, as in Russia, they were of salt-water origin. He agreed with Prof. Ramsay as to the climatal conditions of that period, and had in the west of England seen blocks of porphyry which had been deposited in the midst of small detritus; and these he thought could not have been transported by any other agency than that of ice.

Mr. HOPKINSON mentioned the Permian breccias of the south of Scotland, which are overlain by a deposit of glacial age, so similar to the breccia below as to be with difficulty distinguished from it.

Prof. T. RUPERT JONES argued that without exact evidence the mere character and constituents of the conglomerates afforded no sufficient criterion as to age. In reply to Mr. Godwin-Austen he insisted upon there being direct evidence in Germany and elsewhere of a distinction between the Permian and Triassic series.

Prof. HUGHES was most grateful to Mr. Godwin-Austen for attacking those difficult beds, the Trias and the Permian. In the Vale of Clwyd, which he had recently been mapping, he had found it almost impossible to distinguish them. The bulk of the Permian fossils had by some authors been transferred to the Carboniferous; and in other respects this province had been severely trenched upon. Still, as the New Red Sandstone belonged to a lengthened period of denudation, there was ample room for change of climate. He did not, however, think that the occasional presence of large blocks in a drifted deposit was by itself sufficient proof of glacial action, as when once a block of stone was moved, the carrying power of water was very great. He did not agree with the author as to the exact parallelism between the English and Irish deposits; and cited an instance, near Tebay, of Permian conglomerates passing into Carboniferous limestone, and with no characteristic whatever of a glacial origin. He doubted, therefore, as to the application of a glacial theory to this formation.

Mr. A. TYLOR inquired whether the beds might not be of some intermediate date between the Carboniferous and Quaternary, like certain Belgian beds of the same character, which were possibly of Cretaceous age.

Mr. BLANFORD suggested the possibility of the beds being of sub-

aërial origin. In Persia and Baloochistan, on the borders of what appear to be old lakes, is a vast accumulation of detritus, occasionally containing large blocks of rock, and sometimes ten miles in breadth. The thickness in places appears to be at least 1000 feet; and the whole of this deposit he ascribed to the wash from the hills. He pointed out that the old division of all geological deposits into primary, secondary, &c. was not applicable in India, and, in fact, offered obstacles to research.

Prof. Hull commenced his reply by reading a letter from Prof. Ramsay, who agreed with him that the beds in question at Armagh were of truly Permian age. He maintained, in opposition to Mr. Austen, that there was to be traced a great break between the Permian and Triassic strata. There was, according to his view, as great an unconformity between these beds as there was between the Carboniferous and the Permian. The lines of flexure and disturbance at the commencement and close of the Permian period had been in different directions, and had, he thought, led to some of the discrepancies mentioned by Prof. Hughes. He insisted on the correspondence between the beds at Armagh and those of Worcestershire and Shropshire. As to the difference between the old Permian drift below and the Quaternary drift above, it required to be seen to be appreciated, and was hardly susceptible of description. The old drift, however, was redder and bore greater traces of stratification than the newer drift above. He could not regard the Permian Boulder-beds as belonging to the New Red Sandstone, by which they are, in fact, overlain at the city of Armagh itself. A few limestone pebbles had been found in the old Boulder-beds, but none of them striated; but he did not consider this circumstance of much importance. His main point was the occurrence of Roth-todt-liegende beds in Ireland, where only the Zechstein had previously been known.

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2. Geological Notes on Griqualand West.

By G. W. Stow, Esq., F.G.S.

[Abstract*.]

The geological results of a journey made by Mr. G. W. Stow and Mr. F. H. S. Orpen from the Orange Free State into Griqualand West are communicated by Mr. Stow in this paper, with numerous carefully executed sections and a geological map based on the survey map prepared by Mr. Orpen for the Government. From the junction of the Riet and Modder rivers (south of the Panneveldt Diamond-fields) westward to the junction of the Vaal and the Orange, over the Great Campbell Plateau to Griquatown, Ongeluk, Matsáp, Potgieter, the Langeberg, Witte Zand, and to Kheis and the Schurwe Bergen, the track traversed three degrees of longitude, but nearly 300 miles of road. The return route north-east to Mount Huxley and Daniel's Kuil, and eastward to Likatlong, on the Hart or Kolang River, was nearly as long; and its results form part of the present

* The publication of this paper is deferred.

communication. A subsequent portion of the journey up the Hart, across to the Vaal, down the valley by the diamond-diggings of Hebron and Klipdrift to the Panneveldt, will be treated of in another paper.

From the Modder, first south-westward and then westward, to the junction of the Vaal and Orange, the olive shales of the *Dicynodon*- or Karoo-series, traversed frequently by igneous rocks, form the country, and are seen in some places to lie unconformably on older rocks. The shales reach to the edge of the Campbell Randt, on the other side of the Orange River, and have been, it seems, to a great extent, formed of the débris of those old hills. The oldest rocks of the locality are seen cropping out here and there in the gorges at the foot of the Randt, and consist of metamorphic rocks, greatly denuded, on which the massive and extensive siliceo-calcareous strata of the Great Campbell Plateau lie unconformably. These latter and the breccias of their slopes are coated thickly with enormous travertine deposits. Beyond the Plateau, at Griquatown, a long parallel range of jaspideous rocks comes out from beneath the Campbell Plateau, presenting a wonderful group of yellow, brown, chocolate, and red jaspers, with magnetic and other ironstone, and beautiful seams of blue and yellow crocidolite. The southern portion of this range has long been known as the "Asbestos Mountains" and the "Doornberg." Igneous rock-masses occur around Ongeluk, west of the Jasper range; and then bright-red jasper rocks crop up near Matsáp, succeeded to the west by the parallel quartzite range of Matsáp, and again by other bedded jaspers, which seem to lie in a synclinal of the quartzite rocks, which come up again in the Langeberg. These are succeeded by lower rocks, consisting largely of sandstone, grit, and quartzite, with more or less pervading mica, as far as the journey extended in the Schurwe Bergen, also parallel to the former ranges. The maximum thickness of the successive strata is calculated by the author at 24,000 feet; allowing for possible reduplications, the minimum is regarded as not less than 9000 feet. The details of stratification, successive upheavals, denudation, nature and origin of the salt-pans, escarpments, river-valleys, and other features were treated of by the author, who has supplied a very large collection of specimens illustrative of the phenomena observed in the line of march, and of his numerous sections, maps, and sketches.

Discussion.

Prof. Hull suggested making thin slices from the limestone with a view to microscopic examination, and offered to carry out this suggestion.

Prof. Hughes observed that, by burning a limestone and suddenly plunging it in water, fossils previously invisible were sometimes manifested.

Prof. Rupert Jones pointed out some interesting lithological characters in some of the micaceous, jaspideous, and other rocks sent by Mr. Stow.

3. *On some* Bivalve Entomostraca, *chiefly* Cypridinidæ, *of the* Carboniferous Formations. By Prof. T. Rupert Jones, F.R.S., F.G.S.

(This paper has been withdrawn by permission of the Council.)

[Abstract.]

Bivalved Entomostraca are abundant in many shales and limestones throughout the Carboniferous formations; in the lists published in the 'Transactions of the Geological Society of Glasgow' (vol. ii. 1867, and vol. iii. suppl. 1871) upwards of 50 species are enumerated as known in the coal-fields of Western Scotland alone. Other species have since been recognized in that and other localities. Some of the larger forms of Ostracoda are not rare in the Carboniferous Limestone of Belgium and the British Islands; and, indeed, in some instances they are so plentiful as to constitute masses or bands of limestone, as at Longnor (Derbyshire), Bolland (Yorkshire), Bathgate (Scotland), Poolvash (Isle of Man), Caldy Island (South Wales), Kildare (Ireland), &c. Here and there in the Coal-shales some large forms, especially *Cypridinæ*, also occur.

Many years ago some of these larger Ostracods were figured and described by Professors J. Phillips (1836), M'Coy (1839), and De Koninck (1841), and their Entomostracal relationship pointed out. The collections made by M. J. Bosquet, F.C.G.S., in Belgium, Mr. Joseph Wright, F.G.S., at Cork, Ireland, Mr. J. H. Burrow, M.A., at Settle, Yorkshire, Mr. Young, Glasgow, Mr. Grossart, Salsburgh, Dr. Rankin, Carluke, and others, and submitted to the author and his friend Mr. J. W. Kirkby, have elucidated many obscure points in the history of these old Entomostraca. Numerous other specimens from Ireland, Scotland, Yorkshire, Derbyshire, and the Isle of Man, communicated by friends, have also been studied; and the results will be given in detail in a Monograph by Messrs. Jones and Kirkby, to be published by the Palæontographical Society, and now in the press. The main points of geological interest arrived at are as follows:—

The Entomoconchus of M'Coy proves to have the Cypridinal character of anterior sinus and gape, as intimated by Messrs. Jones and Kirkby in 1863 ('Rept. Brit. Assoc.' for 1863, Tr. Sect. p. 80); and besides *E. Scouleri*, M'Coy, which is found in Belgium, Yorkshire, and Ireland, together with a variety *ovalis* (Ireland), two other species have now been determined, *E. orbicularis* (Cork, Ireland) and *E. globosus* (Beith, Scotland), thanks to the researches of Mr. Joseph Wright, F.G.S., of Belfast, and Mr. John Young, of Glasgow, respectively, all from the Mountain Limestone.

A closely allied genus *Offa** is also indicated, in which the sinus and gape are very slightly pronounced, in a carapace otherwise somewhat resembling the foregoing. Only one species, *O. Barrandiana* (Cork, Ireland), is as yet known.

M'Coy's "*Daphnia primæva*" belongs to *Cypridina* proper,

* *Offa*, a pellet.

judging from the carapace; and besides the Irish specimen, a group of three hundred, found by Dr. Rankin and Mr. John Young in a coprolite from the Lower Limestone Shale, near Carluke, are the only known examples, except some doubtful specimens in the Poolvash limestone of the Isle of Man, and a cast in the Permian limestone of Sunderland. There are several other Carboniferous species of *Cypridina*. *C. radiata* has been found abundantly in the Coal-measure shales of Glasgow by Mr. John Young, and in the Coal-measures of North Staffordshire by Mr. Molyneux, F.G.S. Its carapace-valves possess a curious and characteristic stellate structure. *C. Wrightiana* and *C. Bradyana* are in Mr. J. Wright's collection from the Carboniferous Limestone of Cork. *C. brevimentum* is one of the most abundant of Carboniferous *Cypridinæ*; it is somewhat oval, like *C. primæva*, but has a much greater notch and sinus, and is rather variable in outline. It occurs in the Mountain Limestone of Belgium, Derbyshire, and Ireland, and probably in that of Caldy Island and the Isle of Man.

C. scoriacea, *C. Grossartiana*, *C. Thomsoniana*, *C. Hunteriana*, and *C. Phillipsiana* are from the Lower Carboniferous strata of West Scotland; the last is not rare, and occurs at Cork also. *C. pruniformis* is both Irish and Belgian, from the same geological horizon as the foregoing. *C. oblonga* is from the Cork limestone.

The foregoing *Cypridinæ* have oval-oblong valves notched anteriorly; an allied group from the Mountain Limestone have ovate valves, more or less deeply notched in front, for which, having no recent analogues, we institute a new genus *Cypridinella*. These are common in the Mountain Limestone, and present seven species:—*Cypridinella Cummingii* from the Isle of Man; *C. superciliosa* from Cork (Ireland), Settle (Yorkshire), and Bathgate (Linlithgowshire); *C. clausa* from Cork; *C. Bosqueti*, Visé, Belgium; *C. Maccoyiana* and *C. vomer*, Cork; and *C. monitor*, Settle and Visé. The last is typical of the peculiarly produced carapace, with antero-ventral prow beneath the retiring sinus, a form which reminds one of the profile of such iron-clad naval "rams" as the "Monitor" and "Merrimac."

Carapace-valves like those of *Cypridina*, but impressed with a transverse dorsal or nuchal furrow, characterize the new genus *Cypridinella*, leading us towards the *Cypridella* of De Koninck (restricted); and equally abundant with the foregoing in the Mountain Limestone we have:—(1) *Cypridinella clausa*, Cork; (2) *C. Burrovii*, abundant at Settle, and its variety *longnoriensis*, locally plentiful at Longnor, in Derbyshire; (3) *C. intermedia*, Bathgate; (4) *C. elongata* abundant at Visé, and its variety *hibernica* plentiful at Cork; (5) *C. galea*, Cork; (6) *C. vomer*, and varr. *cultrata* and *uncinata*, Cork; (7) *C. alta*, Cork and Visé; (8) *C. Bosqueti*, Visé.

An additional feature, namely a subcentral tubercle, is the basis for another generic division of the numerous Cypridinoid carapaces of the Mountain Limestone; and amongst this group we have:—(1) Cypridella *Edwardsiana* (*Cypridina*, De Koninck, 1841), which has the general shape of *Cypridinella* and *Cypridellina*, but with a very small

notch; it has, with the aforesaid tubercle, subsidiary smaller tubercles; the larger tubercle on each valve in this species appears to be truncate, and possibly the base of a spine. *C. Edwardsiana* occurs in the Belgian limestone, and is represented at Beith (Ayrshire), Bathgate (Linlithgowshire), and Cork (Ireland) by the variety *septentrionalis*. (2) *C. Koninckiana* has the subcentral tubercle only, with a deep nuchal furrow, apiculate end, and strongly hooked front. It is common at Cork. (3) *C. obsoleta*, from Cork, has tubercle and furrow both faint. (4) *C. Wrightii*, from Cork, approaches *C. cruciata*, De Kon., in shape, but is easily distinguished. (5) *C. quadrata*, from Visé, is longer and squarer than *C. cruciata*, which has not been met with in the British area. (6) *C. cyprelloides*, from Cork, approaches the genus *Cyprella* either as a link or an isomorph.

Sulcuna is a new genus intended to comprise two forms in which the valves are indented with the anterior sinus and notch, and have the general outline of *Cypridella Wrightii*; but the dorsal edge is so deeply incised by the nuchal furrow as to have its anterior moiety raised into a slanting hump, or process pointing backwards and outwards. *S. lepus* and *S. cuniculus* are the two proposed species, both from the Carboniferous Limestone of Cork.

Cyprella, De Koninck (restricted) has an oval or ovate carapace, notched as in *Cypridina* and allied genera; but the surface is transversely striated with parallel furrows or slight step-like markings, associated with a minute reticulate ornament. (1) *C. chrysalidea*, De Koninck, is long, oval, and somewhat pupa-like; it occurs at Settle, as well as in Belgium; but its variety *subannulata*, representing it at Cork, is found at Settle also; and either the type or the variety occurs in the Isle of Man, Derbyshire, and Lintlithgowshire. (2) *C. annulata* (*Cypridina*, De Koninck, 1841), shorter and thicker than the foregoing, occurs in Belgium and at Cork, Settle, and Bathgate. All in the Mountain Limestone. The exact meaning of the details in Prof. De Koninck's figures of *Cypridella* and *Cyprella* appears evident on the study of the large series of specimens that have now been collated.

Returning to some forms more nearly related in the shape of the carapace to *Cypridina*, we find a very exact analogue of Bradycinetus (*B. Rankinianus*) in some carapaces discovered by Dr. Rankin in a small ironstone nodule from the Lower Carboniferous shales of Gare, near Carluke. To Philomedes one form (*Ph. Bairdiana*) is doubtfully referable; it is from Cork. A modification of the Cypridinal carapace is seen in two species of the new genus Rhombina, which has a subcylindrical carapace, with slanting ends, giving a rhomboidal shape to the valves, obliquely truncated at each end with parallel slopes. The antero-dorsal angle is the most prominent; and there is a slight notch beneath it. *Rh. hibernica* and *Rh. belgica* (from Cork and Visé respectively) differ in proportion and outline.

Polycope is a recent Ostracodal genus of the Cladocopal group (*Cypridina* belonging to the *Myodocopa*), and has a suborbicular carapace without a notch, with very slight, if any, indication of the

sinus or place of the notch, and without any dorsal furrow. Such carapaces are not rare in some Lower Carboniferous strata. 1. *Polycope Burrovii* is subglobular, from Settle. 2. *P. simplex*, oval, obliquely truncated at the antero-ventral edge, is common at Cork and Duleek, Ireland; and Dr. Rankin found seventeen in one ironstone nodule from Braidwood, near Carluke. It is somewhat like *Cypridina primæva*; but the want of the notch and beak is its characteristic difference. 3. *P. Youngiana*, from the Lower Limestone of Campsie, near Glasgow, is oval and slightly pinched-in or indented on the antero-ventral quarter, and has a striolate ornament.

This genus is the last described in that portion of the Monograph which is now completed. *Cytherella*, belonging to an allied group, is known to occur in the Mountain Limestone; and *Leperditia, Beyrichia, Kirkbya, Moorea*, and *Entomis*, all palæozoic genera, abound; forms referable probably to *Cythere, Cypris, Candona*, &c. are also known in the Carboniferous formations.

Discussion.

Mr. Gwyn Jeffreys inquired as to the greatest depth at which recent marine Entomostraca had occurred. So far as he knew, they were abundant in the Littoral and Laminarian zones, and very scarce in the Coralline. He was not aware of their occurrence at a great depth.

Prof. T. Rupert Jones stated that in the Carboniferous limestone the Cypridinidæ frequently occur in layers, but he thought these were deposited at no great depth, probably not more than 100 fathoms. The greatest depth from which he had seen Entomostraca from the Atlantic was upwards of 1000 fathoms. These, however, belonged to different genera from those which he had been describing. Their modern congeners, though mounting to the surface in the evening, no doubt descended to considerable depths during the day.

May 14, 1873.

The following communications were read:—

1. *On the genus* Palæocoryne, Duncan & Jenkins, *and its* Affinities. By P. Martin Duncan, M.B.Lond., F.R.S., V.P.G.S., Professor of Geology in King's College, London.

[Plate XIV.]

Five years have elapsed since I completed the description of a very interesting fossil from the lower Carboniferous shales of Ayrshire and Lanarkshire, with the assistance of Mr. H. M. Jenkins, F.G.S.

The results of our labours were read before the Royal Society on June 17, 1869, and were subsequently published in the Philosophical Transactions, vol. clix. p. 693 (1869), under the title of "On *Palæo-*

coryne, a genus of Tubularine Hydrozoa from the Carboniferous formation."

In 1872 Dr. Allman (Monograph of the Hydroida, Ray Society, vol. ii. pp. 172 & 173) criticised the zoological position we had assigned to the fossil, and, whilst expressing his satisfaction concerning the manner in which it had been described and delineated, gave also his reasons for not including *Palæocoryne* amongst the Hydroida.

Some of these reasons, which are stated with Dr. Allman's usual clearness and force, had occurred to us during the difficult task of assigning a classificatory position to the form; and we wrote (*op. cit.* p. 695), "Were it not for the calcareous investment, there would be no difficulty in admitting the fossil amongst the Hydrozoa: and had we not been able to avail ourselves of the affinities of the very anomalous genus *Bimeria* (Wright), the difficulty could hardly have been overcome."

Lately Mr. R. Etheridge, jun., F.G.S., of the Geological Survey of Scotland, has forwarded to me a great number of fragmentary specimens of *Palæocoryne* derived from the lower Carboniferous shales.

These specimens explain certain points of anatomy upon which there was some doubt, and also testify to the correctness of the published descriptions. I have therefore again carefully examined into the whole question of the structures and affinities of the form, and now offer some important additional facts which may influence the decision of palæontologists with regard to the zoological position of this very anomalous form.

The fossils, specimens of which are very numerous, are found associated in the shales with *Fenestellæ*, Crinoidea, and Brachiopoda. Usually they are attached by a dactylose pseudo-cellular base to the margins of the polyzoaria of *Fenestellæ*. The cells of the base communicate, and appear to have a distinct reference to the inequalities of the surface on which it rests. They are covered by a calcareous investment, which contracts as the base increases in height and is continued upwards in the form of a cylindrical stem, which is faintly enlarged in its middle portion, and which is surmounted by a symmetrical expansion resembling in position, and somewhat in appearance, the capital of a pillar.

The erect stem and capitulum are about $\frac{1}{10}$ to $\frac{1}{8}$ inch in height. They were originally hollow, and their cavity was continuous with that of the base. A whorl of elongated and tapering cylindrical processes is given off from the upper margin of the capitulum; and each process is hollow. The processes open by their cavities into the cavity of the capitulum near its upper part. The upper surface of the capitulum thus surrounded is in some specimens projected to form a slight crateriform opening, or metastome, which leads down to the cavity within. The calcareous investment of the stem and capitulum is continued on to the processes, and is elegantly ornamented throughout with grooves, lines, serrations, pits, small spinules and granulations. The grooves and linear ornamentation are longitudinal both on the tentacular processes and on the stem; and the

spinules of the first-mentioned structures often give them a pinnate appearance. Granulation and radiating lines mark the upper part of the capitulum; and these last are especially well seen when the crateriform projection resembling an oral orifice is visible.

The only perforations of the calcareous investment are at the distal end of each tentacular process, and on the upper surface of the capitulum. The general surface is not perforate. There are, however, in a few specimens some few irregular-shaped openings on the underside of one or two tentacular processes; and a few stems present indications of an opening close to the capitulum. It is evident after careful examination that the openings in the distal end of the tentacular processes are normal; and they may have permitted the internal structures to communicate with the outside medium; but the inferior openings are either the result of compression, or of the dislocation of ornamentation. The capitular opening, with its radiating lines and projecting eminence surrounded by the tentacular processes, is a part of the structural œconomy of the form; and even when the upper capitular surface is flat it may be discovered by gentle scraping. It would appear that several flap-like processes enter into the composition of the prominence which ends in the opening, after the fashion of a metastome. The openings in the stems are to be referred to the fracture of a calcareous and hollow process—which is to be seen intact in a few specimens, and broken across at a short distance in others.

The tentacular processes vary in length and in number. The extreme length may be half an inch; and the position of many of them indicates that they were not absolutely rigid. Some are long and others are short in the same whorl; and one specimen may have seven, whilst others may present four, five, eight, or more tentacles. Usually one process is larger than the others, and not symmetrically placed.

There are no cellular dissepiments within the cavities of the capitulum and stem; and the calcareous investment of these structures is thin, readily scraped, and in no way resembles the calcite of the Echinodermata.

In the communication to the Royal Society, my colleague and I represented the form, which clearly could not belong to the Echinodermata, Zoantharia, or Polyzoa, to be one of the Hydroida, having affinities with the recent *Bimeria vestita* (S. Wright).

In this genus there is a chitinous coat, by which sand grains and spicules are mechanically suspended, covering the base, stem, and body and tentacles, leaving an opening for the metastome and for the distal end of the tentacles.

We considered the fossils to be the trophosomes of a hydroid, and that the process beneath the capitulum on the stem might be the gonosome.

The crateriform aperture we believed to be the mouth; and we assumed that the opening at the distal end of the tentacular processes gave exit to a ciliated tentacle during life.

Parasitic (or, rather, placed) upon a *Fenestella*, the form would

participate in its gentle movements, and also in the benefits accruing from the currents in the water developed by the cilia of the Polyzoon.

It was evident that the ornamentation of the hydroid was mimetic of that of the Polyzoon.

Dr. Allman suggests (*op. cit.*) that the ornamentation and the calcareous test do not resemble the structure of the covering of *Bimeria*, that the opening on the distal end of the tentacles was too small for the passage of a well-developed soft tentacle, and that the chambered base is anomalous amongst the class. He considers that the form should be associated with the Rhizopoda.

The lately discovered specimens indicate the manner of the growth and development.

In specimens consisting of a short stem and broad base without the capitulum the stem does not appear to have been fractured, and it is tapering in form and has a narrow superior orifice.

Another specimen (Pl. XIV. fig. 1) resembles those just mentioned, but is taller. The stem has a branch which has been fractured.

Other specimens (figs. 2 & 3) show that the upper part of the capitulum close to or at the metastome is projected (1) in the form of a closed prominence, or (2) as a stem-like continuation with a small aperture on its distal end.

When this stem-like continuation has grown to a considerable length, the appearance of the whole organism is that of a long stem with a central whorl of tentacles.

Many specimens have very large bases. These cover many cells of the *Fenestella* and the intermediate calcareous tissue. It is very difficult to arrive at a satisfactory conclusion whether or not the base is itself divided into cellular compartments. After due consideration I feel disposed to believe that the wide and dactylose base incrusts the *Fenestella*, and that there is a space in the base which is uneven and very irregular in shape, but not cellular *. The shape and general complexity of this space are determined by the outline of the Polyzoon beneath; and there do not appear to be involutions or septum-like processes of the calcified periderm of the Hydroid.

It would appear from the examination of the specimens that the form grew from the base at first without a hard capitulum and tentacles; that it branched in this condition, or had an offshoot destined either to continue the same trophosomal structures, or give rise to those of a different kind and belonging to the gonosome.

The opening in the distal end of the nascent stem could admit of the passage of a polypiform mass with all its tentacles. Under such circumstances, the calcareous stem would be the periderm of the hydrocaulus. The branch would terminate in the same manner as the stem, or else would, under the theory of the Hydroidean affinities of the animal, be the periderm of the gonosome.

With growth, the more or less bell-shaped polypite surmounting

* The cellular appearance shown in Phil. Trans. 1869, plate lxvi. fig. 4, is due to the cells of the *Fenestella*.

the stem may have had the calcareous periderm formed around it to constitute the capitulum, and the greater or less resemblance to *Bimeria* was established.

The prolongation of the stem upwards, and its environment by a whorl of tentacular appendages which could not lead to a metastome, present a difficulty. If the creature was a Hydroid, these tentacular appendages may have been generative instead of assimilative, and may have belonged to the gonosome and not to the trophosome.

The arrangement is so seldom seen in the fossils, and is so evidently a development superadded to an original condition, that it appears to me, that after the trophosome had fulfilled its duties, growth occurred, and the future trophosome was carried upwards with the new stem, and the old tentacles became the supports of the gonosomial apparatus, or that the stem about to be thus developed was always reproductive in its physiology.

The more the specimens with long tentacles and with those which have been fractured rather close to the capitulum are examined, the stronger must be the belief that these elongated processes were stiff at their origin, but capable of much movement at their distal extremities.

The variation in the number and length of the processes is remarkable.

The distal opening, when visible, is small.

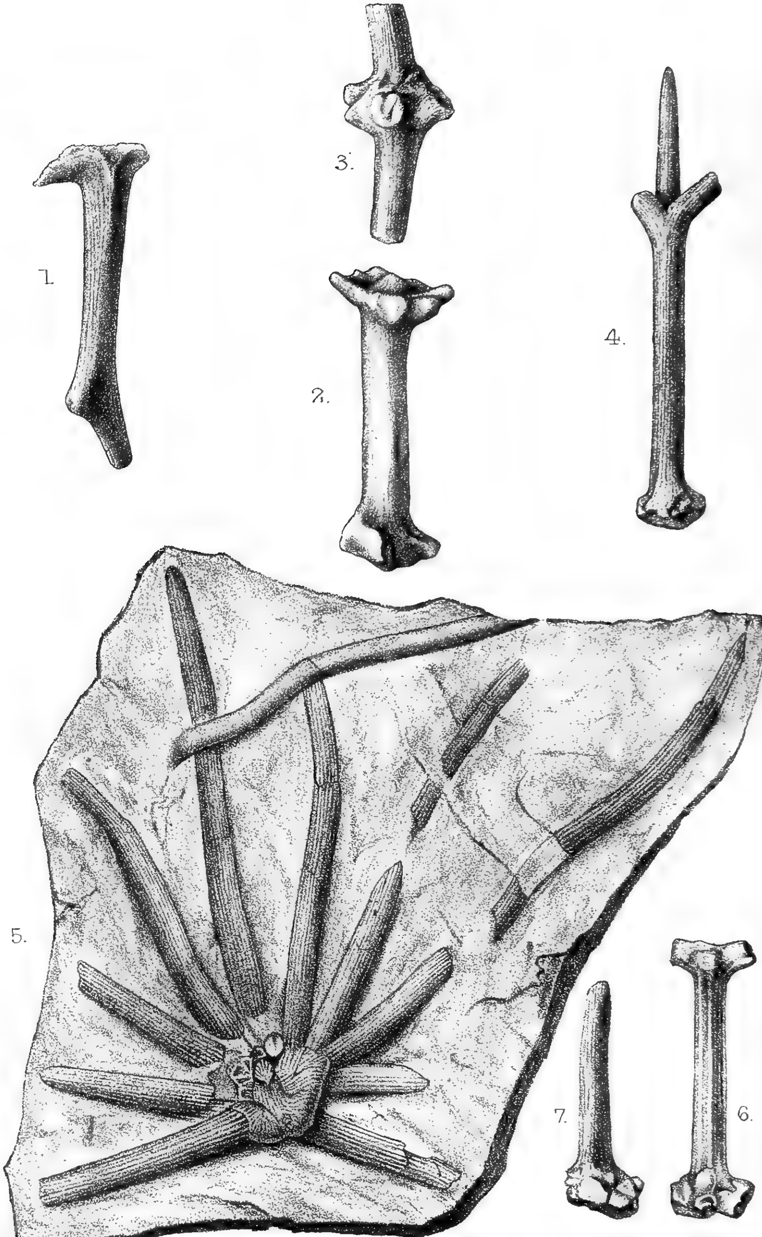
It will be noticed from these observations that Dr. Allman's remarks are not susceptible of much qualification. The form, if it is one of the Hydroida, is anomalous, principally from the ornamentation of a rigid periderm, and from the smallness of the foramen in the distal end of each tentacle. It appears, however, that the cellulosity of the base is doubtful, and that the method of growth is not in opposition to the characteristics of recent Hydroida.

Moreover the anomalous nature of some of the dermal organs of other forms which are found on the same geological horizon must be considered, before abandoning the opinion already expressed concerning the zoological position of *Palæocoryne.*

Thus, there is a group there of cylindrical-shaped corals belonging to the genus *Heterophyllia* (M'Coy). Its species are very well marked; but one has rows of long movable spines with ball-and-socket joints arranged longitudinally on its outside surface. There is nothing like this external arrangement (as seen in *Heterophyllia mirabilis*, Duncan, Phil. Trans. 1867, plate xxxi. fig. 5) in any other known Madreporarian, fossil or recent; and if abnormalities existed in one class, they may have done so in another.

The opinion of Dr. Allman that *Palæocoryne* ought to be classed with the Rhizopoda, entitled as it is to great respect, appears difficult of application.

Doubtless he was impressed especially with the cellulosity of the base of the form; and such rhizopodal genera as *Carpenteria* and *Squammulina* (Carter) probably came within his memory.



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PALÆOCORYNE.

It would appear, in order that *Palæocoryne* might be a Rhizopod, that a cellular base, the stem, capitulum, and tentacles should have been filled with sarcode which was capable of prolongation in the form of pseudopodia from the ends of the tentacles and from the so-called metastome.

But there should be some calcareous structures within the stem and other cavities resembling the irregular external septa of *Squammulina scopula*, Carter, for instance; or the calcareous periderm should be perforate or minutely tubular.

Such septa and perforations do not exist in *Palæocoryne*, whose external form and ornamentation are in my mind opposed to its proposed Rhizopodal alliance.

I venture, then, to suggest that the form should still remain associated with the Tubularine Hydrozoa, in spite of its abnormalities.

EXPLANATION OF PLATE XIV.

Fig. 1. A specimen of *Palæocoryne*, showing the branching of the stem: magnified. The branches are inferior.

2. Specimen showing the metastoma: magnified.
3. Specimen showing the prolongation of the stem past the whorl of tentacles: magnified.
4. Another view of the same in a different specimen: magnified.
5. *Palæocoryne radiata*, from the Phil. Trans. vol. clix. pl. lxvi. fig. 7.
6. *Palæocoryne scotica*, from the Phil. Trans. vol. clix. pl. lxvi. fig. 1.
7. Stem without the capitulum: magnified.

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2. *Notes on* Markings *in the* Chalk *of the* Yorkshire Wolds. By R. Mortimer, Esq.

(Communicated by W. Whitaker, Esq., B.A., F.G.S.)

[Abstract.]

In this paper, which was illustrated by a large series of specimens, the author called attention to some peculiar striated markings resembling structure which he had observed on pieces of chalk from widely distant places on the Yorkshire Wolds. Similar markings had been noticed in the chalk of the south of England; and in 1860 Mr. S. J. Mackie, in an article published in the 'Geologist' (p. 77), alluded to them, and ascribed them to slickensides. From an examination of his own specimens, the author has come to the conclusion that the markings in question are not accidental, nor are they caused by the weathering of the surface of the chalk, or by the percolation of water through overlying chalk. He is of opinion that such needle-shaped striæ, running in such various directions, could not have been produced by the chalk being "shifted, squeezed, and rubbed by the creep of the beds," as supposed by Mr. Mackie—as, if such an action could be exerted on small pieces of chalk, scratching them in various directions, the scratches ought to differ much in thickness

and appearance, which is not the case. Further, two contiguous pieces of chalk, which for the most part would be of the same density and free from hard extraneous particles, would not scratch but polish each other. The author suggests an organic origin for these markings, and regards them as the traces of Corals.

Discussion.

Prof. Duncan, though differing entirely from the author, had been struck with the reasons which he had for his surmises. He exhibited some specimens of recent West-Indian corals, which offered at first sight much resemblance to the character shown in the Chalk. It was to be observed that no reef-building corals are occupants of the deep seas, in which there is little doubt the Chalk was deposited.

Mr. H. Woodward thought that in one or two instances a pseudomorph of a *Siphonia* might be discerned. He could not, however, accept the fibrous structure as organic. It appeared to him to result from the infilling of cavities in the Chalk.

Mr. Whitaker read a note from Mr. Judd, who held that "these specimens were not due to any organic origin. The quasi-crystalline structures known as 'cone-in-cone,' or 'beef,' seemed to him closely related; and in the Yorkshire Chalk an incipient crystallization of this kind had been set up, and the fact of its existence subsequently developed by the solvent action of water, without which it might have remained latent in the body of the Chalk. In one instance the fibrous structure of a portion of the shell of an *Inoceramus* was continuous with that of the matrix." Mr. Whitaker was glad that the author had called attention to the subject, and thought that all would go with him in doubting that the structure was due to slickensides. He mentioned the presence of similar striæ in the Chalk of Surrey. Another observer in Yorkshire had called attention to the greater abundance of the markings in the neighbourhood of fissures than in the solid Chalk.

Mr. Evans mentioned the occurrence of similar structure in the Chalk of Hertfordshire. The portions of the rock in which it occurs are usually harder than the surrounding rock; and in some cases the structure might be seen to pass into that of the ordinary chalk. He considered it to be mainly due to chemical causes.

Mr. Prestwich suggested the desirability of analysis to determine whether there was any difference in the chemical constitution of the fibrous and non-fibrous chalk.

Mr. Forbes, referring to the possibility of this structure being due to crystallization, thought its occurrence in the harder parts of the chalk in favour of this view; chalk, being a nearly pure carbonate of lime, might crystallize either as calcite or aragonite. The specimens in question showed no trace of the peculiar cleavage of calcite, but had a strongly developed fibrous structure resembling aragonite; and as this mineral is the most instable form of crystalline carbonate of lime, it would account for its subsequent amorphous condition. He thought, as these specimens were more commonly found near

joints, that pressure had also assisted in rendering this structure more visible, and that the structure itself might be accounted for by a combination of the forces of crystallization and mechanical pressure.

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3. *On* Platysiagum sclerocephalum, Egerton, *and* Palæospinax priscus, Egerton. By Sir Philip Grey Egerton, Bart., M.P., F.R.S., F.G.S.

In the 13th Decade of the Memoirs of the Geological Survey of the United Kingdom, published in 1872, I described the above-named fossil fishes from the Lias formation of Lyme Regis. Since the issue of that publication I have obtained specimens elucidating parts which were defective in the former examples, and which I consider of sufficient importance to warrant description. On referring to the figure of the former (*Platysiagum*), given on plate 6 of the Decade, it will be seen that the dorsal and anal fins are wanting. This also happens with the several specimens described in the text but not figured. These desiderata are furnished by a fine specimen recently obtained. The two extremities are wanting; the remainder of the fish measures $15\frac{1}{2}$ inches in length. It corresponds very closely in size with the larger of the two specimens described in the Decade. The total length of the fish, if restored, would probably be about 22 inches. The vertical diameter of the trunk is very uniform between the occiput and the dorsal fin, and measures 4 inches. This is a singular character in a Sauroid fish, in which family the body is generally fusiform, tapering gradually from the thoracic arch to the commencement of the caudal fin. The dorsal fin which is here preserved is very singular both in position and structure. It is situated $9\frac{1}{2}$ inches behind the occiput, and occupies a position vertically opposed to the interval between the ventral and anal fins, and extends thence nearly to the origin of the tail. This remote position of the dorsal fin is very unusual in the Sauroid fishes of this age. The organ is composed of 17 or 18 fin-rays occupying a space on the back of one inch and a half. Three or four of the first rays are dermal, increasing gradually in length, and acting as fulcra to the true anterior rays of the fin. The first of the latter carries a fringe of ossicles on its margin; and this feature is continued on the second ray from the point at which it exceeds the length of the first ray. The following rays composing the fin have expanded bases for attachment to the interspinous ossicles. The shafts for some little distance are single and angular; they then take on a flattened character and are traversed by numerous cross joints, and as they recede from the base have successive bifurcations. The most remarkable feature in the structure of this organ is this: at each scission of the fin-ray the posterior limb breaks up into a tuft of raylets, while the anterior portion lengthens singly until the next bifurcation, where a similar process is repeated. This is a structure I am not acquainted with in any other genus of fossil fishes, although an approach to it occurs in the fins of the genus

Spathodactylus of Pictet, from the Neocomian formation of Switzerland. The position of the anal fin, as indicated by some scattered rays, was immediately under the dorsal fin. There is every reason to suppose that the structure of this fin was similar to that of the dorsal fin, since the correspondence of the azygous fins in the Ganoid fishes is of very general occurrence.

PALÆOSPINAX PRISCUS, Egerton.

This fish is described in the 7th article of the 13th Decade of the Memoirs of the Geological Survey of the United Kingdom, from the examination of several specimens in the collection of the Earl of Enniskillen. In all these specimens, however, the position of the second dorsal spine was not indicated. This desideratum is now supplied by a recently acquired example of this fish from the same locality, viz. Lyme Regis. The specimen exhibits the head and trunk of the fish, with the exception of the hinder extremity, and shows the two dorsal fin-spines *in situ*. It measures 16 inches in length, and is probably 3 or 4 inches short of perfection. The number of vertebræ preserved is 95. The first dorsal spine is situated $2\frac{1}{2}$ inches behind the occiput, and occupies a position over the 16th vertebra. The second dorsal spine is fixed $7\frac{1}{2}$ inches from the occiput and 5 inches behind the first, and is over the 50th vertebra. A comparison of these measurements with the corresponding parts in other recent and fossil spine-bearing Placoids shows that *Palæospinax* made, in these respects, the nearest approach to the recent *Cestracion*, as is shown in the following table:—

Palæospinax	1st dorsal	over	the	16th	vertebra,	2nd	over the	50th.
Cestracion	,,	,,	,,	15th	,,	,,	,,	48th.
Drepanephorus	,,	,,	,,	24th	,,	,,	,,	48th.
Acanthias	,,	,,	,,	24th	,,	,,	,,	58th.

The diminution in the size of the vertebra marking the commencement of the caudal series, occurs at the 31st joint; and immediately below this joint there is a patch of light-coloured matter, which is probably coprolitic. A little in advance of this a few delicate fibres are preserved, which were probably derived from the ventral fins. The frame-work of all the fins in this old form was more solid than in the recent Placoids. In both dorsal fins and in the pectoral fins the granular cutaneous outer investment was supported by internal rays of a harder material than mere cartilage; and consequently these are preserved, although the softer parts have perished. Those indicating the position of the ventral fins are situated at five inches from the occiput, or about one third of the entire length of the specimen. There is no trace of the anal fin, although the outlines of the fish are tolerably well preserved—which leads me to suppose that it was merged in the caudal fin, as it is in the recent *Acanthias*. The spines of the dorsal fins are beautifully preserved. The first is the smaller of the two, and is rather stouter and more recurved than the posterior one. The tubercular

ornament on the hinder margin is the same in both. On the whole this Liassic dogfish corresponds most nearly with the *Cestracion* of the present day in its dentition and the arrangement of the dorsal fins; but in the proportion of the head to the trunk, and in the elongated and slender contour of the latter, it has more resemblance to *Acanthias*.

Discussion.

Dr. Günther observed that the families of Sharks were most sharply characterized; and that of the Spinacidæ especially was a very natural group. He did not, in the instance cited, doubt the absence of a separate anal fin, which was one of the characteristics of the Spinacidæ. He drew attention to the fact that the spined sharks showed several singular peculiarities with regard to their geographical distribution. Some belonged to the deep sea, and were found at a depth of 800 fathoms, while others were even more truly pelagie forms, and never approached the shore. Some were found both in the northern and southern hemispheres so similar that specimens from the British seas and from the Straits of Magellan and Australia could not be distinguished. The geographical distribution was of great importance in considering the palæontological aspect of such a case.

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4. *On a new* Genus *of* Silurian Asteriadæ. By Thomas Wright, M.D., F.R.S.E., F.G.S.

[Abstract.]

The specimen described showed the outline of a small Starfish, with a large disk and short rays, in a slab of Wenlock Limestone from Dudley. The outline of the ten rays was described as marked out by the border of small triangular spines, the other plates of the disk and rays being absent. Each ray was terminated by a stem-like multiarticulate process as long as the ray, from towards the extremity of which spring slender lateral processes, giving it a tufted appearance. This Starfish, which is in the collection of Dr. Grindrod, F.G.S., is named by the author *Trichotaster plumiformis*.

Discussion.

Mr. H. Woodward was somewhat doubtful as to the affinities of the specimen, the preservation of which appeared to him hardly sufficient for its specific determination, though of all men Dr. Wright was the best qualified for such a task.

May 28, 1873.

Robert Pictor, Esq., Box, Wilts; Thomas Devine, Esq., of Toronto, Canada; and Charles Smith Scyton, Esq., C.E., Preston Lodge, Walton-on-Thames, were elected Fellows of the Society.

The following communications were read:—

1. *The* Glaciation *of the* Northern part *of the* Lake-district. By J. Clifton Ward, Esq., F.G.S., Assoc. R.S.M., of the Geological Survey of England and Wales.

[Plate XV.]

Contents.

I. Introduction.

The district to which the following paper relates, belongs to the northern half of the English Lake-country. The observations now laid before the Society, with the leave of the Director-General of the Geological Survey, have been collected during the past three years while engaged in the official examination of the geology of the district. The area (map, Pl. XV.) is for the most part included within the one-inch Ordnance map 101 S.E. It contains four large valleys immediately north of the main watershed of the country, three of which, the vales of Thirlmere, of Borrowdale, and of Buttermere and Lorton, drain northward; the fourth, the vale of Ennerdale, drains westwards. Another, the vale of Keswick, drains westward also, including under this head the country between Mell Fell on the east, and Bassenthwaite Lake on the west. The

western side of the Ullswater Valley, draining north-eastward, comes in at the south-east corner. All geologists admit the fact of the glaciation of the district in question; and many notices of the same have been published. It has been my privilege to collect details upon the subject, an *outline* of which I have now the honour of submitting to the Society *.

II. Leading Questions suggested.

The fact of the glaciation being granted, several questions at once suggest themselves.

1. Did the glaciating agent work from north to south?
2. Did it come from within or without the district?
3. Was this agent floating ice, a system of local glaciers, or an unbroken ice-cap?

There are two main sets of observations directly bearing upon these questions:—(1) The direction of the ice-scratches; (2) The direction in which the boulders have been transported.

It will presently be shown in detail that the direction of the former has reference in a *general* way to the valleys in which the groovings are found. And that of the latter, the transport of boulders, can only be learnt by an accurate knowledge of the solid geology of the district. A few words must therefore be said upon this point.

A line drawn from the upper end of Ennerdale Lake, through Honister Crag, along the east side of Derwent Water, and across the lower end of St. John's Vale to Mell Fell, will divide the map (Pl. XV.) diagonally from S.W. to N.E. On the N.W. side of this line lie the Skiddaw Slates, on the S.E. side the volcanic series of Borrowdale. No two sets of rocks could be more utterly unlike each other. On the one hand, old mud rocks, much contorted and cleaved, of a blue-black colour and usually soft, though containing some harder sandy beds; on the other hand, alternations of ancient lava and ash beds, gently rolling in large curves, in some cases cleaved, and for the most part hard. In the north of the district, about Skiddaw, granite and metamorphosed Skiddaw slate occur—rocks of considerable hardness and distinctive appearance.

If, then, the glaciating agent worked in the main from north to south, we should expect to find boulders of Skiddaw Slate, Skiddaw Granite, and the metamorphic rocks associated with it, upon the area occupied by the volcanic series; if from south to north generally, we ought to find boulders of the volcanic series upon the Skiddaw-Slate area. The fact is this. Over the district under consideration, not one boulder of Skiddaw Slate, Skiddaw Granite, or the associated metamorphic rocks, has been found upon the area occupied by the volcanic series; while boulders of the volcanic rocks occur in thousands over a large part of the Skiddaw-Slate area up to certain heights.

* All the minor details of the subject are necessarily reserved for publication in a forthcoming Survey Memoir.

Moreover, among the transported blocks, there are not found any of rocks foreign to the district as a whole. Hence, I think, we may conclude—

1. That the glaciating agent did not work in the main from north to south.

2. That the ice did not come from *without* the district.

It may be objected to this that any effects produced by a great northern ice-cap passing over the district were effaced by the subsequent local glaciers; but I cannot think that this is very probable; surely some foreign boulders would have been left; at any rate, the burden of proof lies with the advocates of this great mountain-ignoring ice-cap.

The third question, just referred to, namely the part played by floating ice, local glaciers, or sheet-ice in the work of glaciation, can only be answered by a careful consideration of the facts. These may be dealt with under the following heads:—

Direction and height of the ice-scratches.

Moraines and boulders.

Drift deposits.

III. Direction and Height of the Ice-scratches.

The general directions of the scratches will be seen at a glance in the accompanying map (Pl. XV.); and only a few words of explanation must be given for each principal valley.

1. *Borrowdale.*—From the upper end of Derwent Water to the higher reaches of Borrowdale the rock-groovings are very numerous. It will be seen that the scratches follow mainly the direction of the several valleys in which they occur, and the direction upon some of the mountain-ridges or tablelands between two *parallel* valleys is the same as that of the valleys. For instance, a great series of N.N.W. and S.S.E. scratches is found ranging from Ullscarf (1) to the head of Derwent Water, at all heights from a little over 2000 feet downwards; these point straight down the Watendlath Valley, and pass completely over the Watendlath and Grange Fells with a very uniform direction. The ridge separating Greenup Gill from Longstrath is likewise crossed by scratches taking the direction of the valleys on either side; and some occur at a height of 1750 feet. Rosthwaite Fell, just north-east of Glaramara (2) forms the western side of the Longstrath Valley; and while many scratches are found to run with the latter, there are some few crossing the Fell above in a N.N.W. direction at a height of 2000 feet.

On the western side of the Derwent, wherever a side combe or valley opens into the main one, sets of tributary groovings join the main-valley series, as from Sourmilk Combe above Seathwaite, from the valley between Seatoller and Honister Pass, and the steep little valley just north of High Scawdel. It is to be noted however, that the main-valley scratches pass over the Fell between the plumbago-mine (just above Seathwaite) and the valley leading

up to Honister Pass. North of Grange, the scratches are almost wholly confined to heights below 1000 feet, with the exception of some at the north end of Castlerigg Fell, which have a N.N.W. and S.S.E. direction up to the verge of the steep Wallow Crag, and are at a height of nearly 1200 feet. On the eastern slopes of Cat Bells the scratches point slightly up and across the ridge.

2. *Thirlmere Valley.*—Here also the main direction of the scratches is that of the valley and its tributaries. They are not very frequent on the steep western flanks of the Helvellyn range, but occur every here and there from 2500 feet (in Browncove) downwards. The scratches over Armboth Fell run in the same direction as those in that of the Watendlath valley, and evidently belong to the same series. The extensive tableland around High Seat (1996 feet) seems free from any rock-groovings above 1500 feet.

3. *Keswick Vale and its smaller side valleys.*—But few scratched surfaces are to be seen in this wide valley; this is in part due to the covering of drift, and in part to the splintering character of the Skiddaw Slate. All the scratches hitherto mentioned, with but few exceptions, occur among the rocks of the Borrowdale volcanic series, which, being harder than the Skiddaw Slate, *generally* retain the markings better. In Keswick Vale, out of nine instances of scratched rocks, three are found upon small bosses of greenstone intruded among the slate.

A few cases of scratches occur along the southern flanks of Blencathra, the direction being with the mountain-side and below 1000 feet. Others are found on either side of Bassenthwaite Lake, where the valley is narrowest. Down the tributary valleys of Newlands and Coledale, sets of scratches also run, following the direction of the valleys.

4. *Buttermere and Lorton Valley.*—On Fleetwith, behind Honister Crag, there are many scratched surfaces from 1750 feet downwards; and in the combes and glens joining the main valley they occur above 1000 feet, and sometimes as high as 1750 feet. But the main-valley scratches are seldom to be found on the mountain-sides above 800 feet, with the exception of a case upon the flanks of Grasmoor, where the height is rather over 1000 feet.

At the southern end of Mellbreak (20), the direction seems to part on either side the mountain; and again at the northern end of Crummock Water, where one set of scratches points straight down the vale of Lorton, and another set runs parallel with Loweswater.

5. *Ennerdale.*—The scratches are less numerous in this valley owing to the large amount of fallen material hiding the steep mountain-sides. Besides some few cases of scratches following the direction of the main valley, below 1000 feet, there are many pointing down the hill-side out of the various combes beneath Pillar (24) and Haycock (25), and down the northern flanks of Kirk Fell (23), some of which are at a height of more than 2000 feet.

6. *Ullswater Valley* (western side of).—Several large valleys run eastwards from the lofty Helvellyn range to join the main valley

in which the lake lies. Each of these has at its head one or more combes, sometimes containing a tarn. Scratches may be found pointing out of each one of these combes, and many others down the lower parts of each valley. In several cases, however, there are also scratches with a direction more or less across the ridges parting valley from valley. Thus, a long narrow ridge separates the valley in which Brothers Water lies from Deepdale; and scratches run directly across the ridge to a height of over 1500 feet. The ridge next to the north also, between Deepdale and Grisedale, is crossed in a similar manner at heights up to 2000 feet below Gavel Pike (37), while Annstone Crag (38) (the north-eastern end of this same ridge) is grooved over its summit (1423) in a N.W. and S.E. direction. The eastern end of the Striding Edge ridge, between Grisedale and Glenridding, is also crossed obliquely by scratches up to a height of 1750 feet.

IV. Moraines and Boulders.

1. *Various kinds of moraine-like mounds.*—Before alluding to the moraines in any detail, it is necessary to say a few words upon the different kinds of moraine-like mounds, as the determination of moraines is not always the easy thing it would at first sight seem to be. The following various kinds of mounds may be distinguished:—

a. True glacial moraines, of a more or less elongated form, though often much cut up by stream-courses, and made up of large and small angular or subangular blocks, some of which are scratched, imbedded in a clayey or sandy matrix; transported blocks of considerable size often lie on the top.

b. Mounds of very similar constitution to the last, formed by the cutting up of an up-valley drift plateau by numerous stream-courses.

c. Mounds of subangular stones and wash, formed where mountain-streams, either occasional or constant, open out into a main valley.

d. Mounds formed by ice-rounded rocks covered with a thin coating of moraine-material or drift.

e. Mounds formed of stratified and false-bedded sand and gravel, quite free from large boulders within, yet frequently having some strewn upon their top.

f. Mounds of scree-material formed at the bottom of a slope, by the sliding of fragments over an incline of snow lying at the base of crags. (I am indebted to Mr. Drew, late from Cashmere, for this suggestion, he having seen mounds of this kind at the foot of snow-slopes among the Himalayas.)

2. *Moraines.*—Very little need here be said about the moraines proper. Most of them belong to the latest set of valley-glaciers, and are confined to the higher parts of the district and the upper ends of large valleys. There is no instance of an undoubted moraine *upon* any of the spreads of drift presently to be noticed, though in some few cases they are found coming down to the borders of this

drift where it attains some elevation. A case in point is the well-marked semicircular moraine beneath the partial combe formed by Wolf Crags, on the southern edge of Matterdale Common, where the base of the moraine and the upper limit of the drift are at a height of 1350 feet. Perhaps the finest examples of large series of moraines are to be found at the head of Ennerdale, up Greenup Gill, and in Longstrath, though they occur more or less in the upper reaches of every valley, and even upon the summit of many watersheds where the ground along the watershed is much higher on either side.

3. *Boulders.*—The *general* transport of boulders from south to north of the district has already been alluded to in opening the subject of this paper. Blocks of the volcanic series of Borrowdale have been carried in immense numbers northwards and north-westwards down the principal valleys on to the area occupied by the Skiddaw Slate. Just an outline only must now be given of some of the special cases of boulder-distribution.

On either side the lower end of St. John's Vale occur masses of a peculiar syenite, fragments of which are readily recognized. Boulders of this rock have been carried in immense numbers eastward towards Penrith; they may be found up to a height of above 1250 feet on Mell Fell and Little Mell Fell, and on the lower parts of the sides of Blencathra. Boulders of the same rock have also been carried westward, *down* the vale of Keswick; and some few occur on the summit of Latrigg, 1200 feet. Further down the vale none are found on the *south-western* side of the Derwent.

Crossing the Thirlmere Valley, between Armboth and Helvellyn, is a very distinctive dyke of quartziferous felspar-porphyry. Boulders of this rock have been carried into the Keswick Vale, and then distributed both to the east and to the west; some of these also occur on the summit of Latrigg; but further west they are not found higher than 800 feet, and are confined to the northern side of the vale.

A large tract of syenite, quite distinct in appearance from the St. John's, stretches from near the N.W. corner of Buttermere Lake over to Ennerdale and south of it. Blocks of this rock are thickly strewn all down the vale of Lorton to Cockermouth, sometimes too at considerable heights, as for instance on Mellbreak (20) (Skiddaw Slate) at above 1500 feet, on Fellbarrow (35) at 1363 feet, and on the southern flanks of Kirk Fell (31) (that Kirk Fell N.E. of Lorton) at 1100 feet. They are far more numerous also on the west side of the Cocker, north of Lorton, than on the east side. A very large number of syenite blocks have also been carried down the Ennerdale valley into the open country beyond.

Up the valley of the Glenderaterra, between Skiddaw and Blencathra, there occurs a small patch of granite and a large tract of hornblende-slate surrounding it. Boulders of the granite (which is white, with black mica) may be traced southwards to the mouth of the valley; and every here and there a boulder has been detected *westward* down Keswick Vale along the foot of Skiddaw, one being found upon the summit of Latrigg. The hornblende-slate boulders

are more numerous and seem to have been carried for the most part westward, a good sprinkling being found upon the summit of Latrigg, and upon the fell-side behind Latrigg up to 1250 feet, also further down the valley on the *north* side up to 800 feet.

Upon Sale Fell (1170 feet), on the west side of Bassenthwaite Lake, is a very small patch of intrusive rock of a peculiar character; boulders of it are found upon the north side of Kirk Fell (31) to a height of nearly 1250 feet, and upon the south side of the watershed uniting Kirk and Broom (30) Fells up to fully 1250 feet; but none have been observed further south, or anywhere to the *north* of Sale Fell itself.

Lastly, with regard to the height at which boulders of the volcanic series are found upon the Skiddaw-Slate area. Upon Matterdale Common and the flanks of Mell Fell they occur up to a height of 1400 feet, on the southern slopes of Blencathra up to 900 feet, upon Latrigg up to 1200 feet, on the south-western slopes of Skiddaw to 800 feet. They are scattered over the whole mountain-group north of Whinlatter Pass up to 1670 feet; and along the eastern flanks of Grisedale and Causey Pikes (32 and 34) they occur *below* 1000 feet. Upon Maiden Moor (1887 feet) such boulders are found to the summit, and at intervals all along the ridge to the extremity of Cat Bells (5). At one spot, however, called Hause Gate, the lowest between Maiden Moor and Cat Bells, they are specially abundant.

Boulders of the volcanic series are plentiful along the east side of the Buttermere and Lorton Valley up to 800 and 900 feet; on the west side, they occur on Mellbreak (20) up to 1500 feet, upon Fellbarrow (35) up to 1360 feet, and at lower elevations.

On Starling Dodd (36—height 2084 feet), but little more than a mile due west from Red Pike (19—height 2478 feet) there are syenite boulders to the very top, the Dodd itself being altered Skiddaw Slate, almost surrounded by syenite *at a lower level*, except quite near the summit of Red Pike.

All over the area occupied by the rocks of the volcanic series, perched blocks of the same kind of rock are very numerous at all elevations up to considerably more than 2000 feet; but details of these cannot here be given.

V. Drift Deposits.

There are three different kinds of deposit in this district belonging to the Glacial Period.

1. *Till.*—Under this head I include patches or spreads of stiff clay stuck full of smoothed and scratched stones and boulders, and unstratified. It occurs every here and there in small patches among the mountains, in rock-sheltered spots, and may frequently be seen in the valleys either by itself or underlying a more gravelly deposit next to be noticed. In some few places the clay is free from stones and boulders.

2. *Drift-gravel.*—This consists of subangular gravel (very rarely

containing bands of sand) in a clayey matrix, with large boulders in and upon it. It sometimes passes down into the Till just described, and either forms sloping plateaux running up the valleys (as the Till alone sometimes does) or wide spreads of a more or less moundy appearance. This deposit is mostly seen in Keswick Vale, and may be traced in parts of the district to at least 1500 or 1600 feet in height.

3. *Sand and gravel.*—Every here and there, along or at the ends of the principal valleys, are mounds having very much the appearance of moraines, but formed of stratified and false-bedded sand and gravel, generally free from *large* boulders, and sometimes quite free from *any* angular blocks whatever, though large boulders almost invariably occur about and *upon* them. It will be necessary to mention a few instances of this deposit.

Some low moundy hills or "hows," as they are called, occur upon the east side of the Cocker, just where the Lorton Vale opens out into the low country. In a large pit by the side of the high road, half a mile north of Lorton, a deposit of sand and gravel is seen dipping S.W., or down the how-side at a high angle; the stones are well rounded; but there are *some* subangular blocks about one foot in length: the height above the sea is from 230 to 300 feet. Between Embleton and Bassenthwaite stations, just north of the line, is a deposit of false-bedded sand and gravel resting upon finely stratified sand with clayey bands, and containing no boulders or angular blocks; its height is from 250 to 300 feet.

At the ends of both the Naddle and the St. John's valleys are long mounds of stratified sand and gravel, with no large boulders *in* but some *upon* them. One of the St. John's-Vale mounds stretches straight across the valley from Bridge House to Hill Top, and has evidently been cut through by the stream. In one section, close by the beck, the sand and gravel deposit is seen to rest upon yellow clay with boulders at the level of the water; in another part a small pit shows coarse subangular gravel on 6 feet of fine stratified sand, its base not seen. In both valleys these mounds are at a height of 500 feet. Another instance of such mounds occurs at Beckees, a little west of Penruddock station; one pit gives 8 feet of sand (base not seen) with a little gravel on top, but free from boulders, though they occur on the surface; the height here is 860 feet.

Lastly, just south of Troutbeck Station and off the Ullswater Road (west of Mell Fell) there is a series of long mounds of stratified sand and subangular gravel, with some boulders within as well as upon the hillocks; they occur between the heights of 900 feet and 1045 feet; but, so far as can be seen by the help of the present pits, the contained boulders are larger at the 1000 feet elevation than at the 900 feet; this, however, *may* be due to accident. In the highest pit-exposure one very large boulder occurs; but it is surrounded by subangular stones in a clayey matrix and *may* be part of a later deposit against the bank of sand and gravel, which only contains much smaller boulders.

Such are the facts, under the heads of *ice-scratches, moraines,*

boulders, and *drift deposits*. Ice in some form has had much to do with most of them; but in what form has it acted?

The direction of the ice-scratches, the way they run along with the main valleys, although sometimes systematically crossing low watersheds, at once suggests sheet or glacier ice originating within the district; floating ice would not produce this regular rock-grooving. The moraines, for the most part, bear witness to glaciers each confined to its own valley and of *late* date.

The boulders give evidence in two directions. First, it is evident that the direction in which they have travelled agrees with that of the uniform ice-scratches; and since these last seem due to a more or less general ice-sheet, there is presumptive evidence that many of the boulders have been moved onwards by the same. Secondly, there are some facts pointing to the transport of boulders in directions other than that of the ice-sheet, and into positions into which neither ice-sheet nor smaller glaciers could have carried them; this second class of facts points to the agency of *floating* ice.

With regard to the drift deposits, while the Till of the district probably represents a *moraine profonde*, the drift-gravel looks like moraine-matter and Till remodelled and partly rounded beneath water; and the mounds of stratified sand and gravel free from boulders seem to indicate currents of water meeting at certain points and forming sand bars when the climate was milder and there was no floating ice.

But before ice-sheet and floating ice can have their limits assigned to them, particular notice must be taken of what must have been the configuration of the land at various stages of submergence, and we must consider whether ice would be likely to float in certain directions or not.

VI. Land-contour at various Stages of Submergence.

In figs. 1–5 the land-contour is given at various points of submergence.

Fig. 1 shows that if the land were submerged to a height of 1000 feet, that part of the lake-district north of the main watershedding line would communicate with that south of it by only one channel, which we may call the "Straits of Dunmail Raise." The height of this pass (Dunmail Raise) is 783 feet. All the other valleys of the area under consideration would be closed fiords, except the great east and west vale of Keswick.

At the 1250 feet submergence the straits of Dunmail Raise would still be the only *through* passage (fig. 2). But instead of each of the other valleys—except the vale of Keswick—being simple fiords, the Buttermere and Borrowdale would communicate by the Honister Straits, and the range of mountains on the east side of the Buttermere and Lorton Valley be split up into three large islands parted from one another by Newlands Straits and Whinlatter Straits.

At 1500 feet (fig. 3), Dunmail Raise would still be the only *through* strait; but now the Ennerdale fiord would communicate

with the Buttermere and Borrowdale waters by the straits of Scarf Gap, and Skiddaw and Blencathra be separated by a strait of some width.

Fig. 1.—*Contour-map, showing the form of the land when the submergence had reached* 1000 feet. Scale 3 miles to $\frac{7}{12}$ inch.

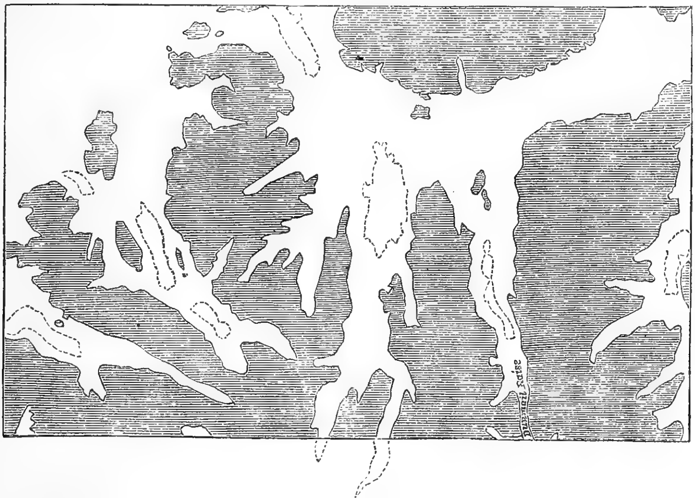
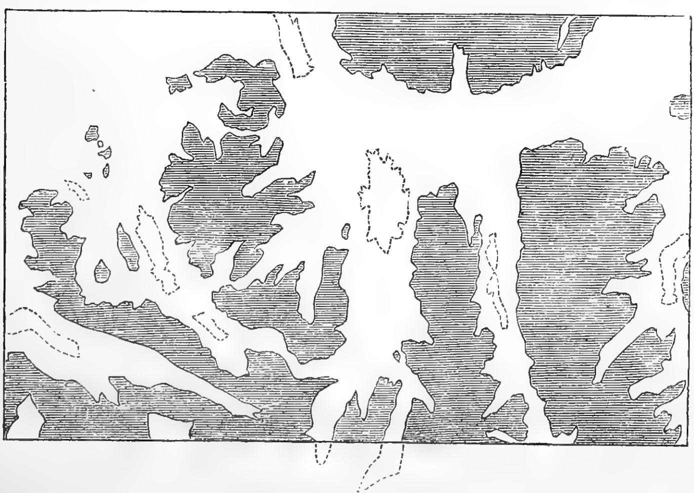


Fig. 2.—*Contour-map, showing the form of the land at* 1250 feet.



At 1750 feet (fig. 4) the breaking up of the land would be complete. Several communications between the northern and southern

parts of the lake-district would exist, and the Helvellyn range form the only tract of land at all continuous.

Fig. 3.—*Contour-map, showing the form of the land at* 1500 feet.

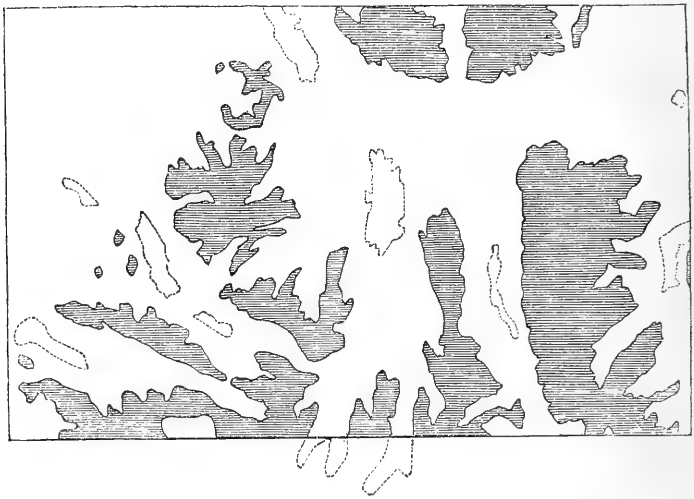
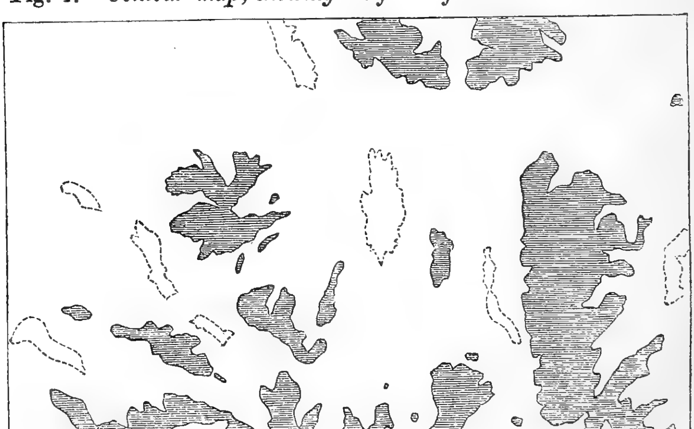
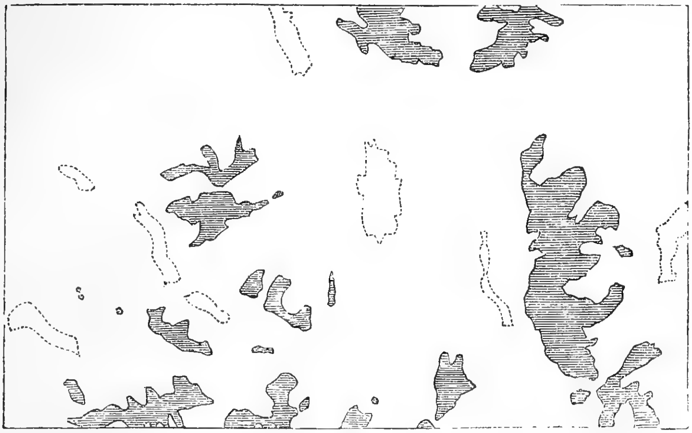


Fig. 4.—*Contour-map, showing the form of the land at* 1750 feet.



At 2000 feet (fig. 5) the whole lake-district would consist merely of scattered islands, of which those of Helvellyn and Scafell would be the most considerable; while at 2500 feet the proportion of land would be very small indeed.

Fig. 5.—*Contour-map, showing the form of the land at* 2000 feet.



VII. Axioms to be borne in mind in drawing Conclusions.

In drawing conclusions from all that has now been brought forward, I would wish to bear in mind the following axioms:—

1. That a great series of glacial scratches, all pointing in the same direction, evidences the onward movement of a sheet of land-ice, and is not likely to be due to drifting and floating ice.

2. That the height to which such *uniform* scratches extend upon the summits of mountains is an index of the amount of hill-area covered by the ice-sheet; and that the height to which they extend upon the sides of valleys is an index of the least thickness of the ice in such valleys.

3. That the onward motion in one constant direction of a great thickness of land-ice would tend to push and carry forward portions of the underlying and surrounding rocks in the same direction.

4. That floating ice might bear boulders in directions in which land-ice could not have transported them.

5. This being the case, it is evident that boulders from very different regions may be commingled, one set being pushed forward by land-ice from one direction, and another set being floated, at a different time, from quite another direction.

6. Since changes in geography affect ocean-currents, boulders may be floated at one stage of submergence in one direction, and at another stage of submergence in some other direction, thus, again, causing boulders from distinct regions to be commingled at the same spot.

7. That where a body of land-ice is confined within the narrowest limits, there, if anywhere, will it be most likely to be pushed over the enclosing walls on one side or the other.

8. That, in such a case, the *push* will be given from that direction

whence the greatest body of ice comes; and consequently the enclosing wall most readily surmounted will be that opposite to this direction.

VIII. Conclusions.

At the commencement of the cold period the glaciers formed small terminal moraines high up the valleys. As the cold increased, the glaciers enlarged, the old moraine matter was partly pushed onwards, partly overridden; at last on the cold attaining its maximum, most of the glaciers were united to form a more or less continuous ice-sheet.

1. *Ice-sheet or confluent-glacier Period.*—This is distinguished by the ice not being *strictly* confined to the valley system in which it originated, but occasionally being thrust by lateral pressure and pressure from behind over watersheds. During this period the ice from the upper reaches of Borrowdale was alone sufficient to fill the valley, and it passed over Castle Crag (900 feet) and exerted much abrading force on squeezing through this the narrowest part of the vale. This great Borrowdale glacier was also continuous with another great ice-sheet which swept in a N.N.W. direction across the Watendlath and Grange Fells, being, it would seem, partly reinforced by ice pressed over from the Thirlmere valley across the watershed by Blea Tarn.

The ice at the head of the present Derwent Water was thus in such quantity that the western part of the Borrowdale glacier was caused to overlap the ridge of Cat Bells, and partly occupy the Vale of Newlands, just as part of the modern Aletsch glacier overlaps a bounding wall and occupies a side valley. Great ice-sheets also came down the Newlands valley and its tributaries to swell the size of the Borrowdale glacier.

The ice in the Thirlmere valley was of such a thickness and so pressed against the western side by the great supplies off the long Helvellyn range, that, as already noticed, it partly escaped across the western watershed south of Armboth Fell, and also took, in great part, a north-westerly course on reaching the lower end of the valley. It would seem, indeed, that the sheets of ice from the Thirlmere and Borrowdale valleys were united in the low ground north of Castlerigg Fell, and that the whole of Keswick Vale from Threlkeld to Bassenthwaite was filled with ice, which abutted against the flanks of Skiddaw, and perhaps of Blencathra, just as the old Rhone glacier abutted against the flanks of the Jura. Like the great old Swiss ice-sheet also, this probably sought an exit from the vale in two directions, one to the east, beneath the slopes of Blencathra, and the other and main one to the west, towards the low ground below the present Bassenthwaite Lake. This mass of ice in Keswick Vale may also have been increased by sheets from the southern slopes of Skiddaw, Blencathra, and the intervening valley of the Glenderaterra.

The ice, sufficient in quantity to block up Keswick Vale where widest, had, on the west, to be squeezed through the narrow neck,

not more than a mile wide, between Dodd and Barf. The result of this seems to have been that much of it was forced over the fells between Whinlatter and Wythop, the higher tops being alone unenveloped.

The Buttermere glacier, though large, probably could not compare with that of Borrowdale, fed by larger areas of fell. Its source was derived from Fleetwith behind Honister Crag, some of the ice passing on the north and some on the south of the Crag. Lower down it was added to by glaciers shed from the mountains and combes on either side, especially by those of the High-Stile and Red-Pike range.

About Scale Force the western side of the glacier would seem to have divided on either side of Mellbreak, part turning due west and joining the ice flowing from Great Borne and Gale Fell, down the valleys on the western side of Mellbreak. At the northern end of Mellbreak the glacier-sheet would seem to have again divided, the main mass continuing down the vale of Lorton, but a branch finding an outlet to the west by way of Loweswater. Very possibly, however, at the time of greatest ice-extension, the ice may more or less have enveloped and passed over the oblong tract of highish ground (from 1000 feet to 1300 feet) between Loweswater and Lorton.

The long straight Ennerdale valley was also at this period in great part filled with ice, the higher feeding-grounds being the north and western slopes of Kirk Fell, Great Gable, and Green Gable, while the many combes along the Pillar range on the south side of the valley each contributed its glacier to the main stream. The ice seems to have passed over Latter Barrow at the east end of Ennerdale Lake, and to have exerted much pressure on emerging from the valley between Crag Fell on the south and Great Borne on the north.

The overriding of parting ridges by the confluent-glacier ice is also very evident on the western side of the Ullswater valley.

2. *Mild Interglacial Period.*—The existence of at least one mild interglacial period is, I think, shown by the following considerations*.

a. *Sand and Gravel mounds.*—The mounds of stratified sand and gravel already mentioned occur up to 800 feet at least without containing large boulders or angular blocks; above this height, up to 1050 feet, similar sand and gravel mounds contain boulders. In both cases, however, boulders, often of large size, are found *upon* the mounds.

The mounds were formed by the meeting of tides and currents during a submergence of the land, and they are consequently formed for the most part at the ends of valleys. The question, however, is, whether a mild period had come on before the submergence began, or whether the country went down beneath the sea ice-clad, and the climate was changed to a mild one before its complete re-elevation. Now the sand and gravel mounds without boulders imply an absence of floating ice; and the fact that boulders are found *on* but not within

* I cannot find any facts in *this* district to suggest a cutting up of the *Ice-sheet Period* by several mild seasons.

the mounds below a certain height, points to a cold period *succeeding* one less cold. Moreover the mounds between 800 and 1000 feet, which contain boulders, show the presence of floating ice at a time when the land was thus far submerged; if a mild period *succeeded* that time and continued until the non-boulder-bearing mounds were formed at various heights between 800 and 250 feet, it is evident that the scattered boulders *upon* the mounds could not have been deposited by floating ice. Hence they must either have been left by a new set of large glaciers, produced after the emergence of the land, or the above theory falls to the ground. That glaciers did exist *after* the emergence of the land is sufficiently evident; but that they were of such size as to spread out into much of the low ground there is no evidence, even if it were likely that great glaciers could ride over mounds of loose sand and leave boulders perched upon them. Therefore the supposition that the mild period occurred during the *re-elevation* of the land is false.

But another supposition is possible. The mild period may have come on before the subsidence even commenced, and have continued until the land had sunk some 800 feet beneath the sea. During the gradual sinking sand and gravel bars might be produced at various heights, when there was no floating ice to transport large boulders. But if cold then began to return, the mounds above 800 feet might contain ice-transported blocks, and boulders would be dropped *upon* the earlier-formed mounds. And this, I think, is what really did happen.

It may, however, be that the boulder-containing mounds above 800 feet were formed *not* during the subsidence, but during the re-elevation, even although they seem from their position to be one with the non-boulder-bearing mounds at slightly lower elevations. For when the land stood at about the same height during subsidence and during elevation, there might be a like tendency to the formation of sand bars at nearly the same spots, only that in the one case the mounds would not contain boulders—during a mild period—and in the other case they would—during the succeeding cold period. Hence, while the *occurrence* of mounds without contained boulders, but having boulders upon them, points to a submergence with a mild period, at all events until the land had sunk some 800 feet, it is merely the *absence* of such mounds at a greater elevation than 800 feet that would suggest the cold period *then* coming on. Mr. James Geikie, in his admirable memoir on "Changes of Climate during the Glacial Period," after pointing out that the mild period had come on before the subsidence commenced, expresses his belief that the cold only began to return when the submergence was approaching its limits. If future investigations in the lake-district should lead to the discovery of mounds without contained boulders at a higher elevation than 800 or 900 feet, my observations would almost completely support his conclusions. I may add that I purposely refrained from consulting Mr. Geikie's paper until I could form my own conclusions from such evidence as these facts afforded, and was then most pleased to find that our inferences were so nearly alike.

So that the facts in this district point to:—1st, the gradual appearance, the continuance, and the disappearance of a great ice-sheet more or less enveloping the district; 2nd, a mild period and gradual subsidence to at least 800 feet; 3rd, a cold period with a continued subsidence and subsequent re-elevation.

b. *Amount of Submergence.*—Finally, the question arises, to what extent was this submergence?

There are some facts which have been brought forward under the head of boulders and their positions, that are more easily explained by the action of floating ice than of land-ice. If we grant that the stratified sand and gravel up to 1000 feet is sufficient evidence of submergence to that point (though at present no marine shells have been detected in these deposits), we may perhaps also conclude that the occurrence of the subangular drift-gravel up to 1500 feet also points to a submergence to that depth. Boulder-evidence strengthens this conviction; thus the boulders borne on to Broom Fell from a couple of miles to the north, at a height of 1200 feet, point clearly to floating ice, as the direction is not that of any possible land-ice stream. On the southern side of Kirk Fell (adjoining Broom Fell), a boulder of the Buttermere syenite rests at nearly 1200 feet; its presence there is most readily explained by floating ice; for it could not have been left by the Buttermere-and-Lorton-Valley glacier when at its largest, because other great sheets of ice, shed from the Grisedale Pike and Whiteside mountains, would have staved off the Buttermere ice more to the west, and prevented its *running up* among the mountains on the east side of the valley.

The syenite boulders upon the top of Starling Dodd, at a height of 2084 feet, are suggestive of submergence even to that amount; for it is difficult to see how they could have got there by the action of land-ice, since the only syenite at an equal height is near the summit of Red Pike (19), one mile due east, upon the same water-shedding line passing over Starling Dodd, which line is depressed between the two summits to 1880 feet. I am therefore inclined to think that these boulders must have been floated either from Red Pike westwards, or northwards from the high syenite mountains upon the south side of Ennerdale and west of Haycock (25). The position of ash and trap boulders on syenite, along Lingcomb Edge (the western boundary of the combe below Red Pike), up to a height of 1750 feet, is also more readily explained by flotation from east to west than by land-ice, when the relative lie of the various rocks is taken into consideration. Many other instances might be given which seem to support the idea of submergence to *over* 1500 feet; and although future evidence may modify opinion upon the subject, I cannot but think it highly probable that the submergence even reached to the height of 2000 feet or rather more.

During this submergence the vast quantity of moraine matter left in all the low grounds by the preexisting ice-sheet, was much remodelled and converted in great part into the subangular drift-gravel already described.

c. *Direction of Marine Currents.*—It becomes an interesting ques-

tion to consider in what directions currents may have flowed to transport boulders. We have already seen that not until the submergence exceeded 1500 feet could there have been any through passage between the southern and northern parts of the present lake-district, except by the straits of Dunmail Raise. That a current passed through these straits *from north to south* seems improbable, since no boulders of the rocks of Skiddaw and Blencathra are found anywhere along the St. John's or Thirlmere valleys. If, however, a current at one time ran through these straits *from south to north*, we should not expect to find boulders of the *Upper* Silurians of the southern part of the lake-district transported north of Dunmail Raise, since there are scarcely any points due south of the straits where the Upper Silurians attain the elevation of 1000 feet. Again, it is somewhat significant that no boulders of the Volcanic series have been detected *up* the valley of the Glenderaterra, between Skiddaw and Blencathra; hence we can scarcely suppose that any current ran through that gap from *south* to north, though many boulders of granite and hornblende slate have travelled *southwards*, and then *principally westwards* towards Bassenthwaite.

Of course it is very difficult to say how much of this transport of boulders has been due to floating and how much to glacier ice; and it is very probable that the directions of transport in the two cases were to a great degree the same. Thus I should be inclined to conclude that, when the submergence had reached 1500 feet, there may have been a current setting through the straits of Dunmail Raise *from south to north*, turning eastward on reaching the end of St. John's Vale, though perhaps sending off a small branch westward as well—also that a current may have set through the straits between Skiddaw and Blencathra *from north to south*, turning for the most part westward on gaining the wide channel of Keswick Vale. It is quite possible, however, that before the submergence had reached 1500 feet, and before the strait had been opened through between Skiddaw and Blencathra, a main current passed through what is now Keswick Vale from west to east, skirting also the whole district on the west, across the end of the Vale of Lorton, and dispersing the greenstone boulders from Sale Fell southwards to Broom Fell. I fully trust that more extended observations to the north and east of the area now described may either confirm or prove the incorrectness of such surmises as to the directions of these old currents.

3. *Period of Local Glaciers and Re-elevation.*—The non-occurrence of true moraines over any part of the area occupied by the drift gravel is, I think, sufficient evidence that there was no return of the great ice-sheet or even of *very* considerable glaciers after the land had been re-elevated. All the main upland valleys, however, had their glaciers during this later cold period; and the fresh-looking moraines now to be seen in them are the last relics of our Glacial Period.

In this paper I have been dealing solely with that part of the district north of the great east and west watershed; I may here add that, so far as I have myself examined the country south of that line,

the evidence seems similar to that already brought forward. Wastdale, Langdale, and Easdale all bear evidence of a great more or less confluent ice-sheet moving southwards from the main watershed, the ice in Langdale and Easdale bearing south-eastwards, that in Wastdale south-westwards, while the many perfect upland moraines belong to the last and smaller set of glaciers. To the confluent-glacier or ice-sheet period are to be assigned also, most probably, moraines found on high passes—as, for instance, in the Stake Pass, between Langstrath and Langdale,—though these may in some cases have been modified by the action of currents during the period of submergence.

IX. Summary.

1. There is no evidence that a great ice-cap from the north ever completely swept over the district, the ice originating in it being probably sufficient to stave off any such northern flow.

2. The ice-scratches, tending *mainly* along the principal valleys, but sometimes crossing watersheds and over high ground, point to a great confluent glacier-sheet, at one time almost completely enveloping a great part of the district.

3. The movement of this ice-sheet was determined, to the north and to the south, by the principal watershed of the lake-district running through its centre, approximately east and west.

4. In that half of the district under consideration, the ice, on its increase from small glaciers to a large ice-sheet, moved onwards a great quantity of rocky material from south to north; this was done partly by the forward pushing of the first-formed moraines, and partly by the ice overriding the same and dragging on the fragments beneath it.

5. This particular district gives no evidence of one or more mild periods occurring in the great epoch of *primary* glaciation; but then the area of the district is but small.

6. The climate, however, had probably become moderate, and the glaciers almost or quite disappeared, before the commencement of the great submergence of the land.

7. During the earlier part of this submergence mounds of sand and gravel were formed in certain positions by tides and currents; and these contain no large boulders. All the old glacial material was also remodelled in great measure and partly rounded.

8. When the land had sunk some 800 or 900 feet the cold began to return, and floating ice transported boulders, which were enclosed in sand and gravel mounds formed *after* that time, and dropped *upon* the older non-boulder-bearing mounds.

9. Not until the submergence had reached over 1500 feet was there any *direct* communication between the northern and southern halves of the lake-district, *except* by the straits of Dunmail Raise.

10. Under such conditions a current very probably ran through these straits from south to north, turning mainly to the east on reaching Keswick Vale, though probably sending a branch off to the west. Hence boulders may have been transported by floating ice in

some of the same directions as they had previously been carried by glacier-ice.

11. A current also probably swept from north to south along the north-western outskirts of the district in question, when the land stood at about the 1200 contour, either during the submergence, or during the re-elevation, or possibly during both. The skirts of this current carried the ice-borne boulders from Sale Fell southwards on to Broom Fell.

12. The situation of stranded boulders in many parts of the district makes it probable that the submergence reached to rather more than 2000 feet.

13. On the re-elevation of the district there was a second land-glaciation, all the higher valleys being more or less filled with ice, which cleared away any marine drift deposited in them; but it would seem that the ice attained nothing like its former extension, as no moraines are found upon the subangular drift-gravel of the wider valleys.

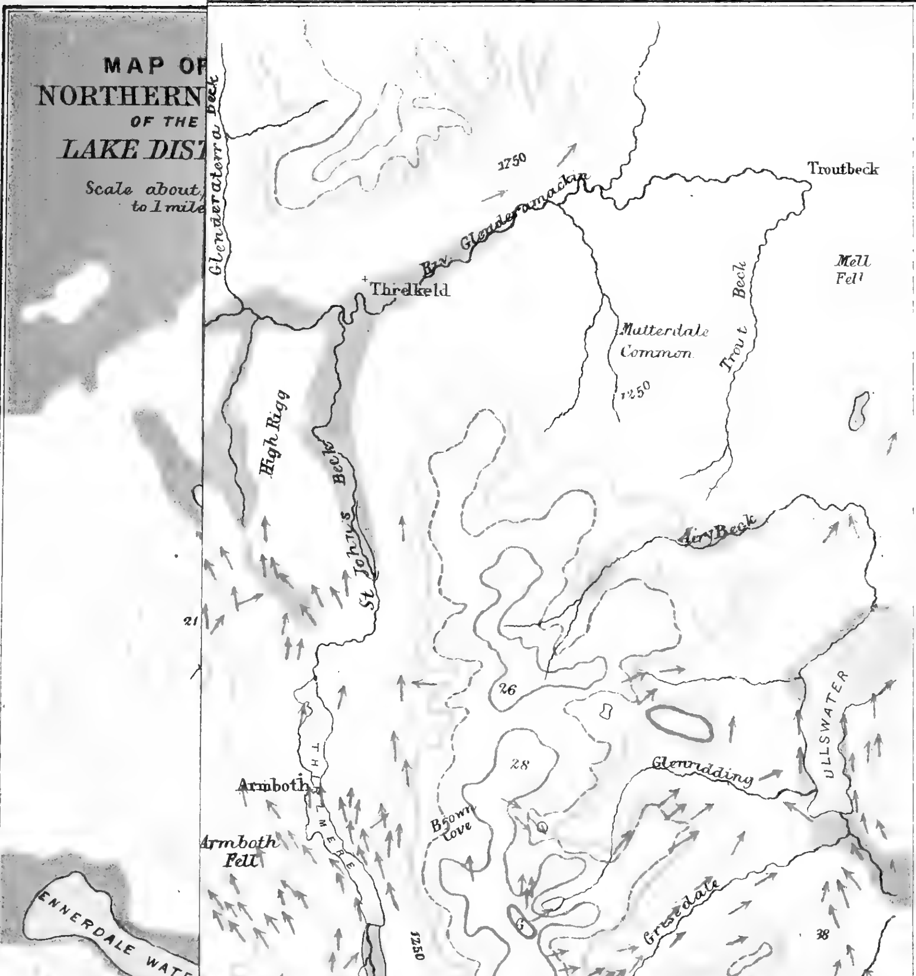
EXPLANATION OF PLATE XV.

Map showing the direction and height of the ice-scratches, together with old lake-beds in the northern part of the lake-district.

Discussion.

Mr. Campbell stated that he had not visited the district. He thanked the author for his able statement of facts. He agreed with his reasoning, which proved the former existence of a "local ice-system" equal to Irish, Welsh, and Scotch systems, in the districts which he had examined and described. With reference to the position of certain boulders at high levels and their transport, it seemed to be an open question, worth the author's consideration on the ground, whether these stones had floated over deep water on ice-rafts, or had been moved by the flowing of deep ice when these hollows were full to the level indicated, and when British local systems were united. In similar cases he had been led to the latter explanation of facts which he had observed in Ireland and elsewhere.

Prof. Ramsay complimented the author on the careful manner in which he had worked out his subject, He thought, however, that many of the principal features described had already been sketched out, though no doubt much knowledge had been added as to details. As to the question of general glaciation, he thought it probable that much of the northern part of Europe had at one time been coated with ice, and to such an extent that it occupied the greater part of the bed of the shallow seas. But even if there were this great ice-sheet, and the general direction of its flow was from north to south, yet there might, in the body of the ice, be upper and undercurrents, going to a certain extent in opposite directions, and mainly guided by the surface configuration of the ground beneath. He thought that some trace of this might be found in existing hilly regions, and that, especially in deep valleys, the upper portion of the ice must, of necessity, have had a tendency to pass over that which



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11. Robinson 2417. _ 12. H 317. 17. High Crag 2443. 18. High Stile, 2643. 19. Red Pike, 2479. 20. Mellbreak, 1676.
21. Carling Knott, 1781. Dodd, 2756. 27. Dollywaggon Pike, 2810. _ 28. Raise, 2889. _ 29. Lords Seat, 1811,
30. Broom Fell, 1670. 3 rling Dodd, 2084. 37. Gavel Pike, 2577. _ 38. Arnstone Crag, 1423. _ 39. Fairfield, 2862.

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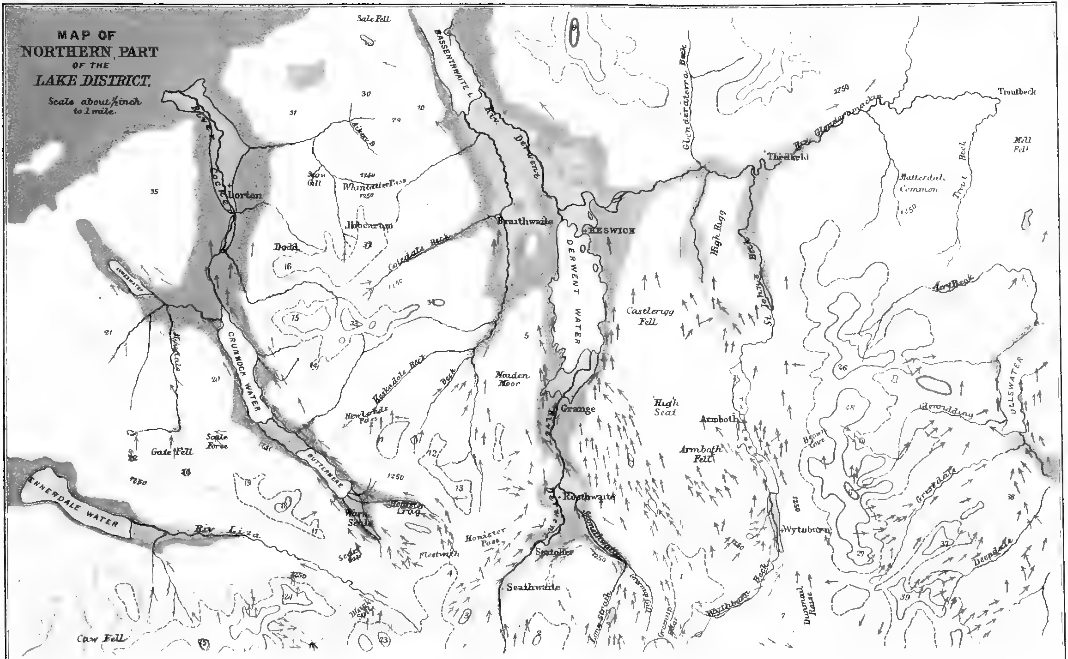

1. Ullscart, 2370. 2. Glaramara, 2560. 3. Base Brown, 2120. 4. Grey Knotts, 2287. 5. Cat Bells, 1482. 6. Helvellyn, 3118. 7. Steel Fell, 1811. 8. Blencathra, 2847. 9. Skiddaw, 3054. 10. Barf, 1536.
11. Robinson, 2417. 12. Hindscarth, 2385. 13. Dale Head, 2473. 14. Whiteless Pike, 2159. 15. Grassmoor, 2791. 16. Whiteside, 2317. 17. High Crag, 2443. 18. High Stile, 2643. 19. Red Pike, 2479. 20. Mellbreak, 1676.
21. Carling Knott, 1781. 22. Great Borne, 2019. 23. Kirk Fell, 2630. 24. Pillar, 2926. 25. Haycock, 2619. 26. Stybarrow Dodd, 2756. 27. Dollywaggon Pike, 2810. 28. Raise, 2889. 29. Lords Seat, 1811.
30. Broom Fell, 1670. 31. Kirk Fell, 1476. 32. Grisedale Pike, 2593. 33. Crag Hill, 2749. 34. Causey Pike, 2082. 35. Fellbarrow, 1363. 36. Starling Dodd, 2084. 37. Gavel Pike, 2577. 38. Arnstone Crag, 1423. 39. Fairfield, 2862.

Mintern Bros. lith.

750 – 1000 ft. 1250 – 1750 ft. 2000 – 3000 ft. Below 500 ft. Filled up Lakes.
The points of the arrows indicate the ice marks.

occupied the bottom of the valley. With regard to oscillation of temperature and of level, he agreed with the author, and was glad to find that his views as to a submergence of about 2000 feet so nearly corresponded with his own. So long as marine remains were found from stage to stage in a certain class of deposits, the probability of similar deposits at a higher level being also marine, was so great that it almost amounted to certainty. He considered that the importance of the latter part of the Glacial period was liable to be underrated; but it was well evinced by the depth (in some cases amounting to 1400 feet) to which some valleys, such as those of North Wales, appeared to have been filled with ice after the re-emergence of the land.

Mr. Ward, in reply, stated that, though he had found striations to a height of from 2000 to 2500 feet, he had not found them on the highest summits of the mountains, where, on the hypothesis of a general ice-sheet, they ought to have occurred. He was therefore not at present prepared to accept the ice-cap theory. In illustration of Prof. Ramsay's view as to the late glacial deposits, he instanced some of the moraines at a high level in the Lake-district, which belonged to the period when the land was still submerged to a depth of 1300 feet or so, and when the cold climate was again supervening.

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2. Alluvial *and* Lacustrine Deposits *and* Glacial Records *of the* Upper-Indus Basin. By Frederic Drew, Esq., LL.D., F.G.S.

Part I. Alluvial Deposits.

The tract of country in which occur the deposits of which I propose to give a somewhat detailed though concise account, is that part of the Maharaja of Kashmir's territory which is drained by the Indus. The greater portion of this country has been visited by travellers whose attention has been drawn to the deposits in question, and who have recorded some observations upon them. While considerable light has been thrown by some of these observers, it has seemed to me well both to add my quota and to try to systematize the facts, so as to prevent the confusion likely to arise from mixing, in description, accumulations of various origin, though they may all be classed in one sense as alluvium, and to see what general conclusions can be drawn from all that we have learned.

The writers who have told most about the alluvial and lacustrine deposits are Col. H. Strachey, Gen. Cunningham, Dr. Thompson, Major Godwin-Austen, and Dr. Stoliczka. Col. Strachey, whose paper on the Physical Geography of Western Tibet is a wonderful store of accurate and valuable information compressed into a small compass, has given in it a description of the alluvium of the neighbouring basin of the Sutlej, with some reference to the corresponding deposits of the Indus; his conclusions I shall discuss further on. Gen. Cunningham, in his book on Ladākh, has given some notices of lacustrine deposits and of the former extension of lakes, which bear on

the subject of the second part of this paper. Dr. Thompson and Dr. Stoliczka have made in passing some close observations, which I am glad to find my own agree with. Major Godwin-Austen has contributed both to this Society and to the Asiatic Society of Bengal much valuable information as to the deposits, and has founded on it important and, it seems to me, correct conclusions: these refer mostly to the lacustrine deposits; and on reaching that part of the subject I shall refer to and make use of his writings.

Though the country has thus been treated of and described by others, it will not be amiss here to recall the chief geographical characteristics of it.

Beyond Kashmir proper, at the back of many ranges of mountains, lie the countries of Gilgit, Baltistān, and Ladākh, all belonging to the drainage-basin of the Indus river, which flows through or by them, from south-east to north-west, for a length of more than 300 miles measured in a straight line, while the average width of the district, at right angles to that, is 120 miles. The elevation of the river itself is about 4200 feet at the lowest part of this course, at the place called Bawanjī; at Skārdū it is about 7500 feet; opposite to Leh it is 10,500 feet; and at the highest point of its course visited by me, where it enters from the Chinese territory, the elevation of the river-bed is 13,700. Of the tributaries that will be mentioned the principal are the rivers of Astor, Gilgit, Drās, and Zanskar, and the great river Shayok, running parallel for such a long distance with the Indus, on the branches of which I have made many observations.

The country drained by all these may be described as a mass or, perhaps better, as a reticulated mass of mountains; the valleys and ravines that penetrate them are almost everywhere narrow, an opening of two or three miles in width being quite exceptional; the few larger flat spaces than that will be described in their turn. Of the mountain-chains, while some have such an irregular, in-and-out course as to defy description by words, and can only be understood from a map, others have a very definite N.W. and S.E. direction. The ordinary height of the ridges may be taken as 20,000 feet; some ranges have a rather higher and some a lower average elevation, while from most rise a few peaks of much greater height.

The chain of mountains that has the greatest influence on the climate and induces the Tibetan, or in the N.W. parts the semi-Tibetan, character of it, is the one that may be described as running from Nanga Parbat and from Deosai through a point between Kashmir and Drās, and thence right away to the S.E. This range intercepts nearly all the supply of moisture from the sea, and causes Baltistān and Ladākh to be countries of extreme dryness: rain is almost unknown there; the hill-sides are bare, not only of trees but of grass; the rocks and the stony surface of the ground are exposed in their nakedness. The rivers are supplied almost entirely from snow, either from the snow-beds which melt away by the end of summer, or from the more permanent snow and the glaciers of those mountains that reach to the snow-limit, which itself

is here very high on account of the small amount of precipitation. Over all the country to be treated of some of the agents which produce alluvial deposits act with great intensity. Frost occurs in winter over the whole; in parts it occurs in summer as well as in winter, the winter temperature of the loftier portions being exceedingly severe. The dislocation, or disjointing, and disintegration of rocks goes on rapidly. The season at which the greatest movement of material occurs is the spring; at that time the fall of masses from the cliffs, the sliding of material in company with snow-slips, and later the rush of torrents laden with débris, arrest the attention, and often enough the steps, of the traveller, and would, I think, be enough to convince the most sceptical that he has in action before him the very agencies that produced the ravines and valleys he is traversing.

I have found it to be most necessary carefully to classify the instances of alluvial deposits met with, to refer each, not only in a general way to the agency that caused it, but to the particular form and degree of that agency; failure to do this will almost surely lead both to erroneous description of the facts and false results of induction. I do not pretend to much that is new in the classification now to be given; for each kind of deposit has often been observed in other countries; but the special character here put on is worthy of attention.

First, *Loosened material.*—This is simply the rock in that state to which the action of the weather on the surface has brought it, *being still unmoved.* The common form is a rugged surface made up of masses of disjointed rock, with but little smaller stuff between them. In other parts the disjointing has been such as to cover the whole surface with comparatively small loose angular stones; while a third form, where the rock is shaly, with harder beds, as of sandstone, interstratified, is a mixed surface of stones and mud. In Ladakh the absence of vegetation leaves all this open to view; and the sight is apt to suggest, to an untrained eye, causes quite unfitted to account for the simple facts.

Second, *Taluses.*—These are the heaps of material which has fallen from crags and cliffs, and lies at the foot of them in slopes, *not having been transported by streams,* simply lying beneath its parent rock, where its own weight brought it, aided, may be, by snow-slips in those cases where rock and snow have taken the same course in falling. These taluses are well known to those familiar with the mountains of our own islands: at Wastwater, in Cumberland, is a very fine example of them; that lake is edged on its south-eastern side by a line of talus that continues for miles, fallen from the cliff that towers above.

The material of a talus lies at the natural limiting angle of slope, which may vary somewhat according to the nature of it, but is generally near 35°.

The above description will apply to all; but there are two or three special forms put on by taluses which are worth a few words.

Fig. 1 shows an ordinary talus: in this the material coming from a

Fig. 1.—*Talus at Hundar, in Nubrā, Ladākh.*

long surface of exposed rock forms a continuous heap, the surface of it (having regard to the size of the fallen pieces) being curiously smooth and the slope very regular.

Fig. 2 shows a form of talus that may be called a "fan talus." The cause of its peculiar shape is this, that the chief source of the fallen stuff composing it is local, not spread over a long line—or at least that the falls from the cliffs become, by some peculiarity in the form of the rocks and cliffs, concentrated nearly to a point be-

Fig. 2.—*Fan Talus at Deskit, in Nubrā, Ladākh.*

fore they can reach their place of rest, and then from that point they spread in a fan-shape in falling and make a surface of loose stones that is in reality part of a cone, of which the slope, in all directions from its apex, is at the same angle at which similar material would have staid in such a talus as that first described.

In Ladākh taluses of both these kinds are everywhere to be seen; the great bare rocky surfaces give rise to very fine examples of this stage of denudation; and of each can one recognize the source, either the overhanging cliff from which the stuff has immediately fallen or the scored surface of the mountain down which the collected material has rolled.

The talus seldom rests high up on the mountain-sides: its foot reaches to a valley, which may be one of the main ones, or may be a steeper and sloping tributary ravine; and from that the slope of loose stones extends regularly upwards, often for 1000 or 2000 feet.

A peculiar case, peculiar more for the degree to which this kind of action has been carried than any thing else, occurs on some comparatively low granite spurs near Leh, the capital of Ladākh. There the rock, disintegrating, has formed a talus at its foot, which, increasing and growing up with successive additions, has risen gradually till the slope of the loose stuff has almost reached the summit of the cliff, of which only a lip, as it were, can be seen above: this must be due to continued action of the disintegrating forces and to the resulting talus being left undisturbed by any other denuding agent.

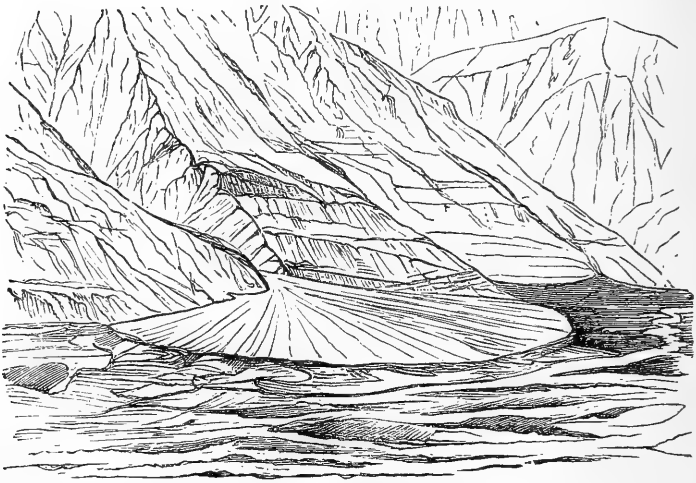
Now and then I have seen a talus that has become consolidated by a solution and cementing of the calcareous material it was composed of; and then, being by later changes partly denuded, there has been left some of this hardened breccia stuck high up on the face of the mountain, puzzling one at first to account for its position.

One other peculiar form put on by taluses, though not, as far as I have seen, occurring on any large scale, may be mentioned, as one likes to account for the smallest detail of stone-arrangement that one sees. I have spoken above of snow and rock together contributing to make a talus: sometimes it happens that a talus of snow forms first, in much such a position and form as the stone-heap itself might acquire; and then upon this snow-heap rolls down the loosened stuff, which therefore finds rest only at the foot, round the edge, of the snow-talus; the melting of this in summer leaves a heap of stones which may be of considerable height, though it is not very likely to increase by additions in successive seasons. Such circumstances as these should be borne in mind when one meets with isolated heaps, not far from the mountain-side, which might otherwise be taken for moraine-heaps. One other result I have noticed: the heap at the foot of the snow talus is not unlikely to take the form of part of a ring abutting at its ends against the mountain, and thus enclosing a hollow which will become the basin of a little lake. There is a lake 40 yards across, which I could account for in this and in no other way, some miles above Pukarkot, in the higher part of the Astor valley.

Third, *Alluvial Fans.*—The accumulations to which I give this name are of great prevalence in Ladākh, and are among the most conspicuous forms of superficial deposits. They are found at the mouths of side-ravines, where they debouch into the plain of a wider valley. I will take a first example from the valley of Nubrā. This

is a flat occupied by gravel of an ordinary river-alluvium, of a width of two or three miles. The level of the valley is 10,000 feet; and from it rise mountains that, on the north-eastern side, run back to a ridge of 20,000 feet, out of which rise peaks of a much greater height. From this ridge come a succession of ravines that join the main Nubrā valley, being, at the point of junction with it, extremely narrow gorges. At the mouth of each of these are alluvial fans, which project out into the flat of the river-alluvium. One of these,

Fig. 3.—*Fan at Tigar, in Nubrā, Ladākh; seen from the mountains behind Charāsa.*



complete and unchanged, is shown in figs 3 & 4. The first sketch gives a view of it got from far up the mountains on the opposite side of the main valley; the other gives a profile view taken from the

Fig. 4.—*Profile view of Fan at Tigar, in Nubrā, Ladākh.*

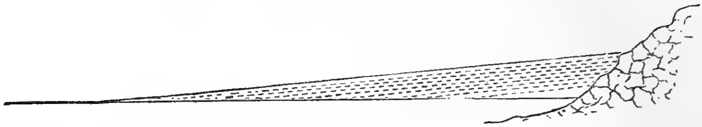
level of that valley. The radii of the fan are about a mile long; the slope of the ground along these radii (which are each in the direction of the greatest slope) is five or six degrees. The fan is properly a flat cone, having its apex at the mouth of the ravine. In this instance the length of the axis, that is to say, the vertical height of the apex above the alluvial plain, will be about 500 feet, the length of the base of the generating triangle being about a mile. It will be observed how very straight is the line of the profile. This is highly characteristic of these fans; and the character is equally marked whatever portion of it we get into view, whatever radius comes into profile. The hard, straight line among the irregular outlines of the mountains adds a strange and unlooked-for feature to the landscape. The radial lines seen in fig. 3 are as faithful representations as I could make of the watercourses with which the surface of the fan is scored; whether we start from the furthest projecting point of the circumference, or edge along the mountains (against which the fan abuts, ending off sharply) to go to the apex at the ravine's mouth, we are always on an equal slope, in this case of 5° or 6°, as before said. In walking across one of these large fans along the path, which is usually made in a curve somewhere between the arc and the chord, one is apt to be continually expecting in a few steps to arrive at the summit of the slope; but again and again is one disappointed, new portions of the cone intervening in succession, until the central radius is reached.

The mode of formation of this fan it is not difficult to trace. Granting the stream of the side-ravine to be carrying down such an amount of detritus as to cause it to be an accumulating, rather than a denuding, stream, and there being such a relation between the carrying-power of the water and the size of the material as to allow of this remaining at a marked slope, we have before us all the conditions necessary. When the alluvial matter which had been accumulating in the ravine reached past its mouth, there was a tendency of the stream to flow over the material it was bringing down, now in one direction, now in another—in every direction, indeed, from the mouth of the gorge as a centre; and along each line, as it flowed, it accumulated material at an equal angle: thus cone after cone was formed, each coating the last, and the sloping fan both rose and spread. Coincident with this there must, in most cases, have been a rising of the bed of the stream back within the ravine. The regularity of the cone was preserved by this cause—namely, that if at any time there was an increase only in one part, say in the direction straight out from the mouth, it could be but temporary; for the next tendency of the water would be to flow, not along that raised part, but off on one side of it, where, still accumulating, it would raise the level of another portion; and so, all the lowest parts being reached by the detritus-bearing water, none but very small unevennesses could occur.

It follows from these considerations that the material accumulates in a general way in layers, but in layers of a peculiar form, not horizontal, rather curved coatings. And indeed this can often be observed

in section; for when a gully has cut through the accumulation in a radial direction, it shows what is drawn in fig. 5, straight-sloping

Fig. 5.—*Radial Section of a Fan.*



parallel layers; but if a section has been made by the main-valley stream across a portion of the fan, we see the lines of accumulation to be in curves, as shown in the diagram, fig. 6. These curves must

Fig. 6.—*Section of a Fan on a chord.*

be, from theory, hyperbolas. The lateral changes of position of the depositing stream, and the partial growth of each layer, are denoted by false-bedding.

It may be remarked that the only difference of form between an alluvial fan such as this and the fan talus sketched in fig. 2 is in the degree of slope.

An unusual case of a fan was observed at Mūrgī, in Nubrā, where the side-stream entered the main valley as a waterfall with a height of about 200 feet. Where this fall was, the fan had its apex; and from that point (on which, of course, the débris, as well as the water itself, fell) it spread just like any other.

The slope of the alluvial fans varies. I have noted the inclination of some fans near Thonde, in Zānskār: four in succession had an angle of 6°, 4°, 6°, and 8°; again, opposite to Leh, the angles 3°, 4°, and 6° occur. It is the case that the smaller fans have the greater slope, and the larger ones the more gentle slope; again, those have a gentle slope that belong to, and lie in front of, ravines that reach far back into the mountains. This must be because such ravines have streams which, draining a larger area, or coming more from snow and glaciers, carry a greater volume of water; and with that greater amount, and consequent greater carrying-power, of the water, the detritus will not remain on a slope of the higher degree, but will only be deposited when it can form for itself a cone or fan of the slope corresponding to the circumstances of the character of material and transporting-power.

In the Nubrā valley, from which I have taken my example, the fans commonly are distinct and separate, with a space of main-river alluvium between each; but it is perhaps as often the case that they have been formed so near to each other as to meet in the course of their growth and to touch each other; and in such cases the layers of each must have slightly overlapped in the forming.

On the left bank of the Indus, opposite Leh, there is a great example of this amalgamation of fans. There, from a succession of ra-

vines of a uniform character, project fans that have coalesced together, and now make a continuous spread of fan-deposits nearly two miles in width, extending along the foot of the mountains for a distance of 30 miles. The fans, although touching, are still distinguishable one from another; the line of junction in the hollow between any two of them is always marked, as well as the ending of the fan against the main-stream alluvium. In fig. 7 is depicted a somewhat similar

Fig. 7.—*Fans united* (five miles south of Pamzālan, Changchenmo, Ladākh).

succession of fans which have met. These are of a greater slope and of a less area; they occur by the side of a feeder of the Changchenmo river, at a height of between 15,000 and 16,000 feet.

In Ladākh it is generally upon alluvial fans that cultivated ground occurs. In that country nothing can be grown without irrigation; and the places are few where the waters of the main rivers, such as the Indus and the Shayok, can be made available for it. The water of the side streams is that which is made use of; and this is led, for these purposes, over the fan-stuff deposited by itself. Still, of the whole fan-area, a very small proportion is tilled. Going along such a space as was above described (opposite to Leh) we may find every three or four miles a village or a hamlet with a cultivated area of fifty to a hundred acres; and the rest will be dry, bare, stony ground. The reason varies for different cases. Sometimes it is that, from the occurrence of ravines such as will be described further on, it is difficult to bring the water on to the surface of the fans; sometimes the quantity of water in the ravine is itself limited, and in summer lessens to far below what would be necessary to irrigate any large proportion of the area of the fan; sometimes, again, the material is such as to make an intractable surface.

Another combination of fans is when, projecting from ravines on opposite sides of a large stream, they meet, or nearly meet, and the river flows confined between them.

In narrow valleys, a fan from one side, even, can reach across the

space and close it up, so as to dam the drainage-waters and form a lake: instances of this have been given by Major Godwin-Austen*; I shall refer to the circumstances in the latter part of this paper. Of another effect of the projection of fans into a narrow valley, I will give an example here:—There is a pass leading out of Rupshū, a district of Ladākh, called Folokonka; this is something over sixteen thousand feet above the sea: a long gradually sloping valley leads up to it; and a similar slope leads down on the other side. The actual pass is made by a fan which comes from a ravine in the mountains that bound the valley on the north; the occurrence of that fan must latterly have determined the position of the pass-summit; and a curious accompaniment of this circumstance is that the water flowing from that ravine is divided, part flowing into one drainage-basin, and part into the other.

There is yet another form of fan to be noticed. Hitherto they have been described as originating from one point, a gap or gorge in a line of mountain, and from there spreading out unbroken by other rocks; and this is truly the general form of them; but it sometimes happens that the form of the ground is different and produces effects less simple. For instance, on the right bank of the Indus, at Leh itself and many miles to the south-east, there is a succession of ravines coming from a great granite-range on the north-east, and widening as they come; the spurs between them, instead of ending off suddenly in a great slope, lessen in height and in width from far back, but continue as jutting rocky spurs on to the river Indus, which itself washes them. The side streams have carried the same sort of material as in other cases. Where the ravine begins to widen may be counted the apex of the fan: from here the stream has at different times spread and wandered; and a form of surface partly resembling the fans has been produced; but the spurs of the hills have both confined the stream and reflected it, so that the simple shape of the low cone is not kept to. For example, the triangular space between the town of Leh and the Indus-alluvium is filled with a deposit modified in its extension by the causes given above; we will call it, for distinction, a "confined fan." It is composed of sand, of granite-stones (some angular, some half-rounded), and of larger blocks of granite: these are a good deal mixed together; but the whole is stratified, with frequent false-bedding. The beds dip and the ground slopes at an angle of 3°, generally to the S.S.W., but with some lateral variations. In this instance the descent from where the widening began to the flat of the Indus is 1200 feet in $3\frac{1}{2}$ miles.

We should now consider the relationship of the fans to the alluvium proper of the main valleys.

If the level of this latter alluvium is remaining, on the whole, stationary (the main river neither deepening its bed nor raising it), and if the fan is undergoing increase, then the fan-stuff will just extend over the alluvium, gradually encroach on it in area; and, stratigraphically, rest upon it. But I think it is a more usual case that the river-alluvium has been increasing contemporaneously with the

* On the Pang Kong district of Ladakh, Journ. As. Soc. Beng. vol. xxxvii.

increase of fan-stuff, that the river and the ravine-stream both were raising their beds; then there will have been an interstratification of the two deposits at the fan-edges as they were at successive epochs, a lapping for a short distance of one set of alluvial beds over the other.

I have sometimes observed in section an interstratification such as to suggest the above origin—beds of well-rounded materials and of sand among the less-worn fan-stuff; for indeed the latter, being nearer its source, is seldom thoroughly rounded.

Perhaps I have not hitherto said enough as to the substance of the alluvial fans. The form of them, indeed, depends but little upon its character, though doubtless the slope is affected not alone by the quantity of water that flows down, but also by the size of the masses that are weathered off from the mountains and the facility with they will further disintegrate. Some fans are made up of semi-angular pieces of stone, of such material as hardened shale and slate, of sizes seldom above that of an octavo volume; others, that come from granitic mountains, are made up of more or less rounded blocks of granite, which are often as much as 4 feet in diameter; but among these will be found gravel and sand of the same material; in some cases the material is such as to merit the description "unrounded."

The crossing of such stony plains or slopes as these fans constitute is a great feature in Ladākh travelling; many a weary mile of rough road unsheltered from either rain or wind does one pass over between the villages or the halting-places, alternately scorched by the heat, which is doubled by reflection from the bare stones, and penetrated by the cold wind that rises as the day declines.

We have hitherto treated of fans that are whole and undenuded, and have considered the formation of them in that complete form; now we have to trace the changed state that many of them are found in, the result of the denuding-action they have been exposed to.

What would be the effect if the Nubrā river changing its course, as rivers do that flow over a level alluvial plain, should attack and eat into the circumference of the fan we first looked at? It would cut off a segment, cut a cliff in the substance of the fan, which cliff would increase in height as the action proceeded inwards. At the north-western end of the line of fans opposite Leh just such a thing has occurred; there a cliff has been made by the river Indus in the substance of some of the fans, from 50 to 100 feet in height.

The annexed diagram, fig. 8, will illustrate this and other cases. The fan had formerly extended from *a* to *d*, where it joined the river-alluvium flat *d*, *e*; but the river has in one of its lateral deviations cut it back from *d* to *c*, and made a low cliff at *c*, and then retired and left its alluvium on that space.

Where the river cuts deeper back, so as to make a higher cliff, and where there is a considerable volume of water flowing over the fan from the side ravine, more complicated results follow, the nature of which I must describe somewhat in detail. We will suppose the river to have cut its way back as far as *b*, and made a cliff in the fan a hundred or two hundred feet in height. The ravine-stream discharged from

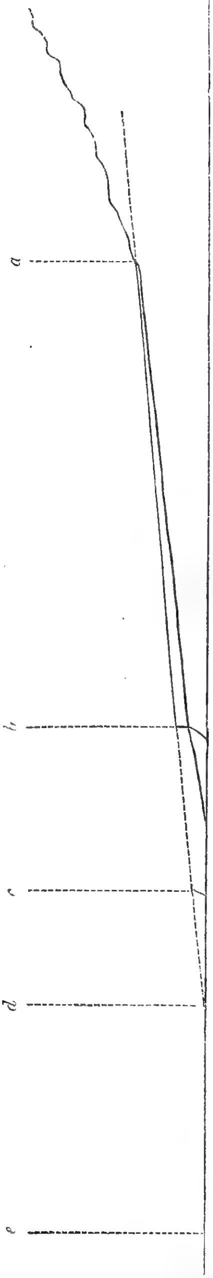


Fig. 8.—*Diagram to explain the Denudation of a Fan.*

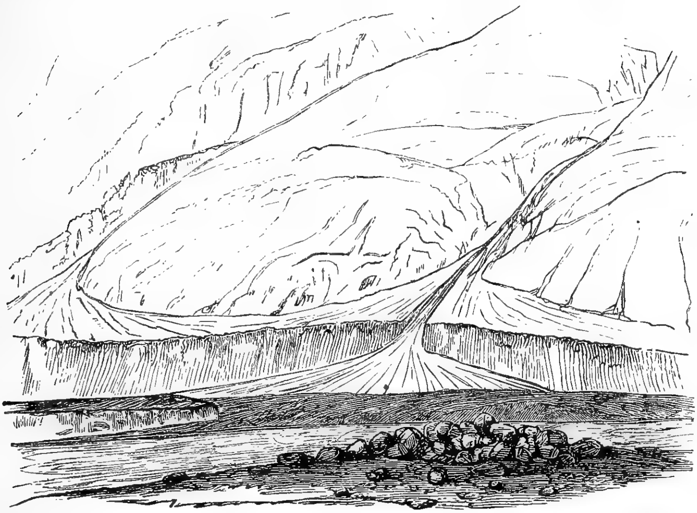
the gorge at *a*, which used to flow regularly down the fan from *a* to *d*, may, indeed, for a time flow nearer the mountains down another of the radial water-courses to a part of the fan-edge where the river has not eaten its way in; but it is sure some time or other to find its way over a part of the fan that leads to the cliff; over this, then, it will fall; and it will soon cut a channel for itself in the cliff-edge, and continue to cut back that channel so as to modify the shape of its bed as far back as *a* or even further, into the ravine itself. This action however, may, be interrupted by some cause originating at or near the mouth of the ravine, which shall deflect the river-course and lead it either, as before, down an unbroken part of the fan or to another portion of the cliff, in which last case a similar action would be set up there. Thus we often see gullies cut in the cliff-edge where the stream had for a time flowed, but from which it had been stopped above before any very deep channel was made. Ultimately, however, the stream is sure to deepen one course for itself so much and so far back that all further wanderings are prevented, and for the future it will flow out along a deep gully between cliffs of the fan-alluvium.

Yet another effect is produced: over this newly cut gully, while it is forming, will come with the water the usual detritus; and that will (with the addition of the waste of the fan itself involved in the cutting of the gully) fall and settle at the foot of the cliff in a more or less modified talus; as this rises, and the gully deepens, the talus and the new stream-bed will meet, and the stream will then flow out over the talus, and eventually, by still adding material, lessen the angle of the talus-slope and make a new fan with nearly the same inclination as the old one had, projecting in front of the fan-cliff. In the diagrammatic section, fig. 8, the lower unbroken line from *a* to *b* denotes the position of the new stream-bed in the gully, while the continuation of it

towards *e* marks the new or secondary fan projecting in front of the cliff *b*.

As it is always satisfactory to refer to actual cases, I annex a sketch, fig. 9, taken in the Changchenmo valley (the altitude of

Fig. 9.—*Fan cut into by the River, with secondary Fan formed in front* (four miles south of Pamzālan, Changchenmo, Ladākh).



which is 15,000 feet), of a compound fan which is a fair example of the action which I have been describing.

It is likely that the cutting of a notch in the cliff begins early in the formation of the cliff; but it is not likely to become the permanent bed of the stream until the cliff has been worked a good way back. One often sees many such notches at the end of gullies now dry that once held a stream: but we must also remember that there is a tendency of the waters to separate; so that only part may have gone to produce them; it is not until the denudation of the gully has gone back to the gorge that the course and the holding together of the waters are determined for the future. It may be remarked that there is no instance, as far as I know, of *more* than one deep gully leading from the cliff to the mouth of the ravine, although, as in some of the fans opposite Pitak, near Leh, small secondary fans project from several of the radiating water-courses without the gully having been denuded far back.

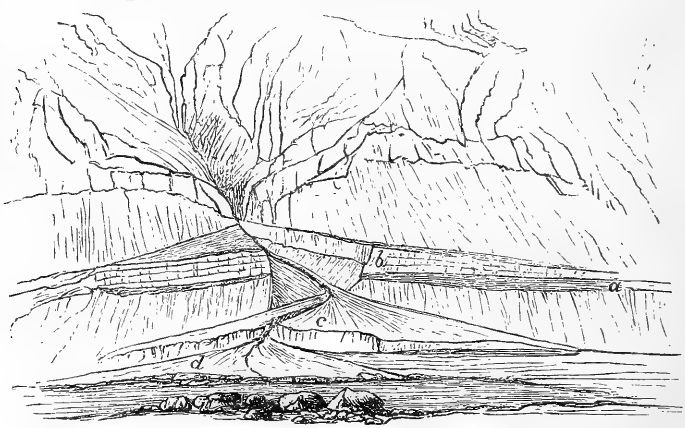
Thus far we have dealt with cases in which neither the fan-stream nor the mountain has had any tendency of itself to lower its bed; for in the last instances the fan-stream would not have cut through its bed but for the accident of the river, by its side action, making a cliff which necessitated a readjustment of the slope of the bed of the ravine. But we often enough meet with evidence of the

general deepening of the bed of the river, of the denudation by it of its own alluvium, and also of a change in character of the fan-streams from accumulators to denuders; and this will now be brought forward.

First comes what must be a rare case; for I have met with only one instance of it. High up the Indus valley, on the right bank, close to the Chinese frontier, is a fan which spreads on to the alluvial flat and has not been cut into by the great river; its slope is 4°, its radius $1\frac{1}{2}$ mile; in this fan is a gully which originates by the mouth of the ravine from which the fan spreads, and continuing on gets to a depth of 70 feet; but it dies away altogether as the fan meets the plain. At the time I was there (being summer) the ravine and gully were perfectly dry; but the gully must have been made by the same stream that produced the fan, which therefore had changed from an accumulator to a denuder without the extraneous cause of the formation of a cliff, and without any similar change on the part of the main river to which it was tributary.

Our next set of cases depend on the main river having lowered its bed, having cut through beds of alluvium formed by itself. These, again, with reference to the fans, divide themselves into two kinds:—the first where, though the main stream has become a denuder, the fan-stream has remained an accumulator; the second where the fan-stream no longer accumulates material. The sketch, fig. 10, illustrates the former class of cases, and at the same time

Fig. 10.—*Triple Fan* (three miles above Tsotu, Changchenmo, Ladākh).



represents a beautiful instance of the compound fan; I did not bring it forward before, only because the case is complicated by the circumstances we have now to consider. A careful look at the sketch (which is of a fan in the Changchenmo valley) will enable one to to make out these details:—The dark horizontal shading at *a*, and that corresponding to it on the left is alluvium of the main stream; it continues far below as well, but is there hidden by fallen stuff;

the letter *b* is upon the original fan formed in front of the ravine, which fan was formed at the time the main river was at the level of its highest alluvium-bed, and at that time was complete and unbroken. The course of events was, that after the formation of that fan the main river lowered its bed, cutting through its own alluvium; this caused the fan-stream to cut through its fan and make the gully now shown in the middle of it. No mere lateral denuding action of the river would have enabled that gully to become so deep as to reach below the beds of alluvium upon which the fan was formed. Downward denudation of the river-stream, combined with a side action, made the cliff in the two deposits shown at *a* and *b* and on the opposite side, and brought about the central gully in the same way as was described in detail further back. Though, however, the river had become a denuder of its bed, the fan-stream remained an accumulator; for it then threw out the secondary fan, *c*; this in its turn was cut into by the river, whether with side action alone or whether accompanied with further bed-deepening I am not sure, and (a gully being cut in the second) a third fan was thrown out (marked *d*), which is now exposed to the waters of the river. In this case, where the river is distinctly a denuder and the side-stream has a tendency to accumulate deposit, there is a struggle between the two; much that is brought down by the side-stream is carried away by the larger one; in consequence the side-stream itself is forced to denude some of its own formation, and there remains but a skeleton of the former deposit.

If, however, with an increased denuding-power of the river the fan-stream also loses its tendency to accumulate, the result is a deep ravine cut in the fan, leading to the main stream, with no secondary form of the deposit at its mouth: this is a frequent case; and here lies the cause of what was alluded to some way back, the common difficulty of bringing the waters of the side-stream over any of the land made by its deposits. The smooth surface of a fan cut off by a high river-cliff, with a sudden deep ravine with nearly vertical sides towards the middle of it, two or three hundred feet deep, is a common phenomenon all through the country; and I think it is altogether explained on the supposition of the above succession of events*. I have taken my examples of fans from Ladākh proper; but perfectly similar ones occur all over Baltistān and as far down the Indus valley as I have been—that is, to the junction of the Astor river.

4. *Alluvium.*—Although the accumulations last considered are in a general sense alluvial, yet for the purposes of my classification I must count as alluvium proper those deposits of a stream or

* I have met with a few, but with very few, instances of the denudation of the fan-material by the fan-stream having proceeded in such a way as to make a *wide* valley in the fan and not a mere gully; and in these cases terraces of the fan-alluvium have been left. This I connect with the denudation of the main-river alluvium in *stages*, with periods of rest. Such terraces in the fan-valleys occur in the Changchenmo valley, where, as will be mentioned further on, the river-alluvium also shows a succession of terraces.

river, which, while sloping in a direction coinciding with the general course of the stream, are as regards any line at right angles to that direction, level; that is, the surface of them is a plain inclined with the valley of the river, and not appreciably curving over to the sides of it; the word, with this meaning, agrees with one of the ordinary uses of it. And while thus keeping it distinct from the more terrestrial deposits on the one hand, I wish to separate it on the other from the lacustrine beds which, as we shall see, occur in some of the same valleys.

Alluvium, in this slightly restricted sense, is found in large quantities in the country of the Upper Indus; and the mode of occurrence of it denotes important changes of condition, which we may endeavour to analyze. It occurs at all levels; it may begin as high up in the heart of the mountains as the ravines in their ramifications reach; it is steep in the higher parts, when composed of fragments yet undisintegrated, and makes a more gentle slope lower down, when due to streams of greater volume and when consisting of smaller material. I shall mention instances of alluvium in various localities, beginning with the higher tributaries of the Indus.

Near the sources of the Zānskār river is a flat alluvial plain about two miles wide between the mountains, part of the uplands of Rupshū. This is sometimes described as a tableland, but is really an elevated but level valley; the flat of it is 15,000 feet above the sea; the mountains around it are between 19,000 and 20,000 feet. At one side of this flat, one comes to a sudden drop, a ravine 500 feet deep and some hundred yards across, with a flat at the bottom through which flows a stream in many channels. The sides of the ravine are cliffs, in part worn into pinnacles, in part sheer, and in part weathered into shingly slopes; the composition is beds of rounded pebbles, mostly of limestone, regularly stratified: the whole thickness of this deposit is the 500 feet of the cliff; for at the foot of it the rock has been reached. The whole spread of flat ground mentioned, which is on the right bank, must be composed for a great depth, probably a depth equal to this, of the same alluvial deposit; on the left bank is a similar high cliff of the same pebble-beds, rising to the same height at the summit, at which level there is quite a narrow plateau; and behind that rise the mountains.

Such deposits as this Capt. Henry Strachey has described in his paper on Western Tibet; and he has spoken of some on a still larger scale of thickness in the higher parts of the Sutlej basin. He refers them to a marine origin, and, remarking on the existence of the strata up to a height of 16,500 feet, supposes that they must have been laid out under a general sea while the framework of the mountain was in its present form, and afterwards upheaved by the equable rising of a whole continent*. I think that there is no necessity for the supposition, and even that there are positive objections to it. In the first place, above this very flat surface at this particular valley (which on the marine theory must have been formed by a deposition of material in a narrow strait) there

* H. Strachey on the Physical Geography of Western Tibet, p. 20.

are no marks of littoral action, no beaches or beach-marks—which would necessarily have been made, and, in the general unaltered state of the surface, have remained. Again, the strata are often or generally seen to be not exactly horizontal; they have a slight dip down in the direction of the drainage. This slope of the beds is sometimes with difficulty perceptible, but is often seen to be one or two degrees and sometimes more. The surface of the terraces or flat slopes in the same direction; and that direction varies as much as the course of the valleys themselves changes. The relation of these high-level deposits to alluvium in lower portions of the streams (such as will next be described) increases the reasons for connecting them with river rather than with marine action.

The alleged inadequacy of existing streams to form such a deposit as that 500 feet of pebbly alluvium I see no reason for. My experience of streams convinces me that their ordinary daily work in many cases, and in others their work in the spring time, is to bring down from the mountains, and to bring into form and deposit in their beds, just such material as that. When a stream once gets a tendency to raise its bed, there is no reason why it should stop at ten or twenty feet, nor why, as long as there are mountains behind to be wasted, it should not go on doing the same for 500 feet; only it must raise its bed not at one part of its course only, but generally far up and down the valley. Such an alluvium, then, as described, I put down to the action of the very stream that now flows at the bottom of the ravine cut through; it may, indeed, formerly have had a greater volume and force from the existence of a different state of climate. Nor is there any greater difficulty for the same stream to have cut the ravine through that alluvium than to have deposited it; for the deposition at that portion of its course implies the bringing of material of a certain character down from above; the cutting away of the alluvium only implies a carrying of that same material further down towards the sea. The reason why a stream should at part of its course at one time accumulate material and at another time carry away the same material is well worth seeking for; but of the fact that streams do so I have no doubt.

Two days' march to the south-west of the place of the last-described alluvium, on another branch of the Zānskār river, is a partly similar deposit. Here, for ten miles or so, the valley that leads down from the Bara Lacha Pass, between mountain-spurs, is a rather narrow flat (at a level of about 15,000 feet) sloping gently to the north-east, the way the drainage runs, and cut through by a ravine to the depth of about 200 feet, which exposes the beds of alluvium which make up the substance of the flat of the plateau down to the present level of the streams, and perhaps lower still; for the rocky base is not exposed. Other streams join the main one from both sides; and it is impossible always to say to which of them parts of the alluvium are due; in truth the substance of both must have been intermingled and interstratified. I wish particularly to note a phenomenon observed here, the meaning of which shall be discussed when a similar one

has been described from another spot. By the meeting of the Sarchu streams there are beds in this mass of alluvium which slope or dip at an angle of 30° away from the mountains; these I believe to belong to and to have been deposited by the Sarchu side stream. Again, two miles below, by the junction of this stream from the Bara Lacha Pass with the one called the Isārap, at a distance of near a mile from the mountains, the same level plateau of alluvium is cut through to a similar depth of some 200 feet; and in the section of the alluvial beds is shown what at first sight might be taken for false-bedding on a very large scale; that is, the beds of alluvium slope sometimes away from the mountains and sometimes towards them, other strata covering them horizontally. Stranger still, the beds are sometimes in curved lines. Leaving for the present the attempt to explain this, we will go on with the alluvium at other places.

I have not followed the course of these streams all the way down; but, from another direction, I have visited a part of their valley about fifty miles below, they having by that time joined together. From the valley of Chāh down to Padam, the chief place of Zānskār (at elevations varying as one goes down, from 13,000 to 11,300 feet), nearly everywhere along the valley are remains of alluvium, generally well-stratified pebbly alluvium, at various heights, up to 400 feet above the stream, the river here flowing between rocks which it has cut into below the base of the alluvium. There are other deposits, of lacustrine origin, the description of which I reserve for another occasion.

At Padam the valley debouches into a wide open space. Here, between the mountains, is a plain of a considerable extent, which may be described as a triangle whose base of seven miles lies north-west and south-east, with a perpendicular of five miles to the north-east. The two chief branches of the Zānskār river, the one which we have followed from the south-east, and another coming from the north-west, here meet, and flow away north-eastwards. The plain is covered with alluvial deposits, partly fan-stuff from the minor streams, and partly alluvium, both old and recent, of these two chief streams. I have no exact notes of the level to which this old alluvium is found, but have an impression that the terraces are about 200 feet above the present level of the water. Below this, down to Zanglā, the valley narrows, and, from the side fans nearly meeting, little space is left for river-alluvium, of which, however, I see terraces here and there from 60 to 80 feet above the stream. Afterwards the river flows in a narrow gorge, impassable, except in winter on the ice; and for this part of its course, to its confluence with the Indus, I am unacquainted with its alluvium.

There is hardly any valley, whether of the larger tributary rivers of the Indus or of the smaller side-streams, that does not present phenomena similar to those described. In parts where the valley is narrowed there may be no remains of the old alluvium, all having been denuded on the last down-cutting of the river-bed; but where the valley widens, even but a little, there will be found some rem-

nant, some strip of narrow terrace, which shows that the stream had formerly accumulated alluvium up to that level; and where, from the nature of the rock or other cause, there is any wide opening in the valley, there occur spreads of alluvium, plateaux, often high above the stream. I do not find in the various valleys any thing like a constant height to which the alluvium may occur, nor do I think it likely that there has been everywhere one thickness up to which it accumulated: this must have depended on the fall of the stream, which itself must have been varied by the character of the material it had to deal with in different parts of its course and the amount of water flowing in the different branches.

In determining these facts, one must be careful not to confuse the deposits of the side fan-producing streams with those of the larger river; for a fan, when denuded back, may well, at first sight, give one the impression of a former great vertical accumulation of alluvium of the river, whereas really it has no such relationship with that river as for its altitude to imply that. With careful attention it is always possible to separate the different kinds of alluvium if the falls of the two streams are markedly different—the alluvial terrace, which may be but a narrow strip or may be a wide spread of the larger valley, and the fan of the branch one, which, even after the wreck it has undergone through various forms of denudation, will show the slightly curved surface of the low cone-form in which it accumulated. If the fall of the two streams at their junction was about the same, the two alluviums will have formed one general plateau, and the relation of both streams to the height of it may be considered together.

Varying from the above causes as they do, the alluvial plateaux show themselves at such heights above their streams as 150 feet and 250 feet commonly, 300 and 400 feet also not being rare. It should, too, be remarked that above the highest remaining portion of alluvium there may have been at any given spot a yet higher level, which was destroyed in the first recommencing of downward denudation.

We will now add further instances of alluvium by which to test the above generalizations. We will go to some of the branches of the Shayok river—that great tributary of the Indus which drains a large mountain-area on the north-east of it.

At Khardong, two marches from Leh on the road to Nubrā, is a remarkable instance of a deep-cut alluvium. The village stands on the narrow remaining portion of a high alluvial plateau, composed of débris of various sizes, even of large blocks. This was formed on a slope of some degrees; it has been cut into by ravines, which show something like 800 feet of it in steep cliffs; in one part is an isolated rock that had been enclosed in the alluvium, and has since been freed from it, except that a few beds are still adhering to its sides. The road descends on a stony slope to the bottom of the ravine, and keeps between the high alluvial cliffs, which shut out the view of the mountains, although these at no great distance bound the alluvial terraces.

In the Chonglung ravine, a northern branch of the Changchenmo valley, are, here and there, terraces of alluvium, 70 feet above the present level of the water; and at one spot, a meeting of valleys, there is an alluvial plateau 200 or 250 feet high. In the Changchenmo valley itself, in the ten miles from the place where the road to Yarkand first reaches it, to Kyām where the hot springs are, one sees alluvium at various levels; I counted six terraces of alluvium, all due to the Changchenmo stream, in 150 feet of vertical height: these terraces occupied but a narrow width each; for the greater part of the breadth of the valley is held by the recent gravel, over which the stream flows in many channels *. It is at this part that occur the compound fans of the side streams, one of which was described in an earlier part of this paper, as well as the fans with valleys cut in terraces in them.

Opposite Kyām, on the right bank, is a great vertical cliff of alluvium, about 200 feet high. A little lower down, at the place where travellers to Yarkand ford the river, the river-cliff shows river-alluvium of clay and sand covered, I think, by fan-stuff; here is repeated, in a more marked and, so to say, exaggerated form, that phenomenon of highly inclined and curved beds of alluvium described as occurring in the higher part of the basin of the Zānskār river. Here in Changchenmo the strata are bent up, in some parts very suddenly; and, indeed, some are bent over beyond the perpendicular. Only some of the strata have been so affected, the beds below and above being flat. I can only account for these phenomena in one way; and I think the explanation will suffice. The former extension of glaciers in the Himalayas is well acknowledged; and I shall start from it as from a determined fact, without going into proof of it, though I hope to bring before the Society details about it. If a large glacier had its end at the spot where this unusual form of alluvium now occurs, it must have had a course of near forty miles, whether it originated in the northern or in the eastern mountains: immediately in front of such a glacier alluvium would probably have been forming in considerable quantity; it is open to one to suppose that the bed of the stream immediately in front of the foot of the glacier was rising by means of such accumulations. During that time the glacier may have risen on to such alluvium by encroachment forward, or it may have been lapped round by the deposit, or partly both. In any of these cases a further forward advance of the glacier (such as may occur any year when the balance of movement and waste is slightly disturbed) would be apt to press the alluvium-gravel in such a way as to crumple it up, to force it into curves, which may have been sudden bends near at hand, and getting more gentle further off, the distance to which the effect was felt probably varying with the thickness of the deposit acted on and

* Spread both on this recent alluvium and on a terrace 15 or 20 feet above it, but not interbedded in the higher deposits, are many large blocks of white limestone, derived from the hills on the right bank higher up. How they came where they are is not very clear. They may have been brought by unusual sudden floods, or, perhaps more probably, by river-ice.

the extent of the advance. There would be a tendency of the surface of the alluvium to assume a waved form; but this would probably soon be counteracted by the levelling effect of denudation by the stream and further deposition. If after doing this the glacier definitely retreated, the disturbance of the beds would be completely hidden until further changes exposed it in section. To the above cause I attribute both the curvature seen in this Changchenmo alluvium and the straight false-bedding-like slope of the beds (at such angles as 30°) in proximity to curvature, of the Tsārap and its branches. The slopes seen may be but parts of a long curve; or the action of the glacier may have been in some cases more an underprising and tilting one than I have described it.

Another example of alluvial terraces is shown in the sketch, fig. 7. Here is a cliff of the alluvium of a branch of the Changchenmo river (that leading down from Māsinuk Pass) which is about 120 feet high, and very regular and persistent; the slope of the surface of the terrace down the direction of the valley is $1\frac{1}{2}°$. It is instructive to trace from this sketch that, although the river has cut down to such a depth in its own alluvium, the fans behind have not been cut into by their streams. At the time I passed them (in the month of August) they were, indeed, dry, but there were marks of shallow watercourses on them: it is clear the water did not come down in volume enough to reach the edge of the alluvium cliff and cut a notch, and cut back a gully for itself, as has occurred in so many other instances.

In the Tainyār valley, down which another tributary of the Shayok flows, the sides of the ravine are great cliffs, showing at first 350 feet of alluvium, continuing from the top of the cliff down to the present level of the stream. Some beds are coarse and contain boulders; some are of fine gravel. The strata slope down the valley at an angle of 2° or 3°, the present stream-bed having a rather greater fall than that. Further down the cliffs get higher, and a still greater thickness of deposit is shown in section; but here come on lacustrine beds, the description of which I defer; and as what deposits I have seen on the Shayok itself are either lacustrine or closely connected with lacustrine ones, I shall now pass to the alluvium of the Indus proper.

Where the Indus enters Ladākh from Chinese Tibet, it is flowing towards the north-west through a flat alluvial plain at an elevation of about 13,700 feet above the sea. This flat, which lies between mountains of 19,000 and 20,000 feet high, has a width of about two miles, and continues like that for a length of some five-and-twenty miles. It is so regular in slope that when one stands on it the horizon of the curvature of the earth can be seen in both directions, both up and down the valley. The river flows gently, winding through the flat at the rate of two miles an hour. After this it bends suddenly to the south-west, and traverses a range of granite mountains, and then nearly regains the north-westerly direction; flowing still over alluvium in the same gentle manner, it traverses another twenty-five miles beyond the distance first mentioned.

At one part I reckoned the river to be 80 yards wide, while flowing at the rate of $2\frac{1}{2}$ miles an hour; elsewhere it had divided and flowed in more than one channel. Near the end of our distance the width of the flat had increased to 4 miles; and just below this the river-channel was between 200 and 300 yards across, but with this width was shallow, as it was here fordable at a depth not over 3 feet. The surface of the alluvium is thinly covered with grass.

The alluvial substance is for the most part clay—sometimes a dark-coloured clay and sometimes drab clay—while at some parts not lately washed by the river it was sandy. I was there in August of 1869, and for a time the water of the river was perfectly clear; but one day we found it had become muddy; this had no doubt been caused by an increased melting of the snow in the still higher parts of the river-basin, within the Chinese territory. A very little more increase of volume would have brought the water over the banks, and caused a deposit of silt and an addition to the alluvium. For this reason I do not see the necessity of supposing that this alluvial flat was deposited in a lake; it does not differ from the river-alluviums of our own country, which are made by the overflow of the water at flood times. The flat, though level to the eye, really slopes with the valley at a gradient corresponding to the fall of the water. At the same time I think it very probable that the low slope of the river and its alluvium was due to obstacles that came across the valley just below, which first probably caused a lake, and then a rearrangement of the bed to its present angle.

Along that flat down to the first villages that occur in the valley, called Nimu and Mad, one does not see alluvium at a higher level than that recently formed. Below, at the place called Maiya, is a section showing beds of felspathic and micaceous sand and light-drab clay, the deposit of the river, at a height of 30 feet above the stream. From this point onwards, for some 60 miles, the Indus flows through the narrow rocky region called "Rong." Here I have not followed it*.

* I will put down here in a note a short account of certain deposits in and near this part which I have not been able satisfactorily to account for or to classify. Near that uppermost flat of the Indus, in the tract called Kokzhung, where "sand-hills" is marked on the eight-miles-to-an-inch map of the G. T. Survey, is a line of low hills or mounds connected, occupying on the right bank of the river, between its alluvium and the fans from the mountains, a space about 4 miles in length and 300 to 400 yards in width, and rising to a height of 300 or 400 feet. Again, 3 or 4 miles further to the south-west is an isolated mound, a few hundred yards long, about 100 yards wide, and 60 feet high, of like character. There is no flat top or terrace. The surface is undulating or, rather, moundy. The substance of the hills is mixed: there is small granite, gravel, and even sand; there are stones of shale, chert, sandstone, and greenstone; and there are larger boulders of granite: for the most part it is either angular or only partly rounded. I should have no difficulty in considering the hills to be merely an old moraine left by some glacier, but that I observed at one part of them, near the north-west end, strata of clay, sand, and pebbles, dipping towards the hills (north-east) at an angle of 40°. I estimated a thickness of 60 to 80 feet of these beds; and there may have been more.

Again, behind the village of Chushal, in the basin of the Pangkong Lake, are mounds 200 feet and more high, which are composed partly of irre-

From Upshi, at the lower end of the Rong, to Tagnā or Staknā the river flows between banks of 100 or 200 feet height, which are composed for the most part of fan-stuff; that is to say, the river has cut through the fans of the side streams. With this fan-stuff, however, the more rounded alluvium of the river itself is seen to be interstratified. Below Tagnā a change takes place. The fall of the river-bed is less; there is no cliff of alluvium bounding it. We get on to a flat of clay soil that, with a width increasing sometimes to a mile or more, extends to a length of 12 miles along the course of the river, as far as the village of Pitak, near Leh. This is a repetition, so to say, of the alluvial plain in the high part of the Indus where we began our description, 100 miles up; and there is not, as far as I know, another such case till we get to Skardū, which is 150 miles down the valley. Over this flat the waters of the river are brought in channels for irrigation without difficulty, as its ordinary level is but a few feet below that of the flat. Here, as in the earlier case, I am disposed to think that the low slope of the river-bed and of the alluvium which corresponds was made by a checking of the waters at a spot not far below, which made a lake, and caused a rearrangement of the river-bed slope for some distance back, and brought about the deposit of more than usually fine alluvial matter—the present surface, however, being alluvial, not lacustrine.

Below this the Indus takes to a deep rocky ravine, which is impassable; the road leaves its course for a space. Here are some interesting phenomena which will be treated of under the head of lake-deposits.

Beyond this, again, we meet, at various spots, with alluvial deposits quite similar to those so often described. Just below Khalsī are seen two terraces of pebbly alluvium—one, on which the road goes, about 100 feet above the river, the other some 300 feet higher still. Twenty miles lower down, at Achinathang, there is a definite terrace-level 250 feet above the river. The cliff-section shows that for all that height down to the water-level it is composed of pebble beds exactly parallel to the surface of the water—that is to say, inclining slightly down the valley. Higher beds there are in this neighbourhood; but these will be classed under a different head.

I have not many more definite notes of the occurrence of such alluvium as we have been confining our attention to in the valley proper of the Indus. There remain to be described of this class of deposit some instances to be met with in the tributaries that come in from the south-west side, including the remarkable plains of Kargil, Drās, and Deosai.

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gular débris, and partly of strata of pebble-beds, sand, and clay, some of it laminated.

While suggesting that these last may be connected with the lacustrine deposits (though the moundy form in which they are now left presents some difficulties), I must acknowledge myself unable to account for the occurrence of the upheaved or sloping beds first described, and must be content to leave them for further observation or for the inferences of others.

At Kargil there is an unusual widening-out of low ground among the higher mountains. This must be connected with the occurrence of a great thickness of soft clay and sandstone beds of Tertiary age among the metamorphic and granitic rocks. Two streams, from the south-east and south-west, meet at Kargil, and flow to the Indus. The space included between the two, for some four miles above the junction, is covered by a great deposit of alluvial gravel. From the level of the meeting of the two streams (which is near 9000 feet above the sea) one rises in succession on to four different terraces, the last being 600 feet above the part of the stream opposite to it. This whole thickness, being an alluvium of more or less rounded stuff, is seen by the river-bank. The terraces are of different widths; the higher ones make plains several square miles in extent.

As far as this part of the deposit is concerned I have no difficulty in counting it an ordinary old alluvium of the two streams. One is confirmed in this by observing that there is a general slope of the terraces towards Kargil, and that the old river-cliffs which bound them are more or less parallel to the general run of one of the streams, the one that flows from Suru. Towards Pāskim, however, are certain deposits at a higher relative level still, which, perhaps, are not thus to be accounted for. I had not an opportunity of following them out, and must leave them with this notice in the hope that some other traveller will turn his attention to them.

At Drās, which is high up another of the tributary streams, there is another expanse of alluvium of some importance. While on the south side of the stream that flows by that place the mountains continue lofty and steep, to the north the higher mountains have retreated, and low irregular spurs that come from them end off so as to leave a flat space about two miles wide and three long. This is for the most part covered with alluvium in terraces of two or three different levels. The uppermost is about 120 feet above the stream. It occupies a good space in the northern part of the valley, and is repeated on the right bank as well. The material is a mixed one of small pebbles, stones of moderate size, and larger masses. The second terrace is but 40 feet above the stream; and out of it here and there rocks protrude. Again, at one part there is a third terrace, occupying but a small space, 25 feet above the water. The gravel at some parts extends down to the level of the stream; at others this flows in a rocky channel. I annex a section (fig. 11) across the valley from north to south, to show the way in which the alluvium has lapped round the projecting rocks, and the stream, after traversing at different times all parts in width of the valley, at last has cut a channel for itself in the rock.

We now come to one of the most remarkable and interesting tracts of all this country—the tableland of Deosai. There is a tributary of the Drās river, called the Shigar*. If one were to follow up that, one would be led by a gradual rise, until at a level of over 12,000 feet a large open plateau would be reached; this is

* Not to be confounded with the Shigar river that joins the Indus at Skardū.

Fig. 11.—*Section running north and south through Drās.* (Horizontal scale $2\frac{1}{2}$ miles to 1 inch. Vertical scale doubled.)

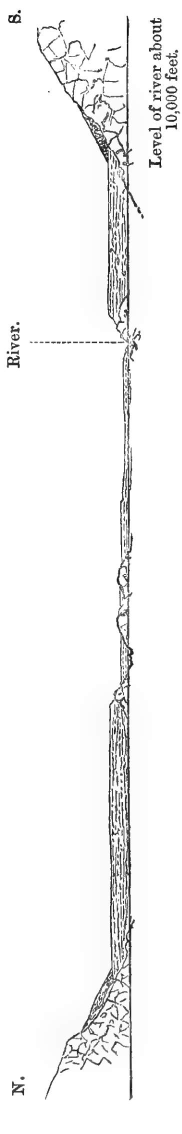
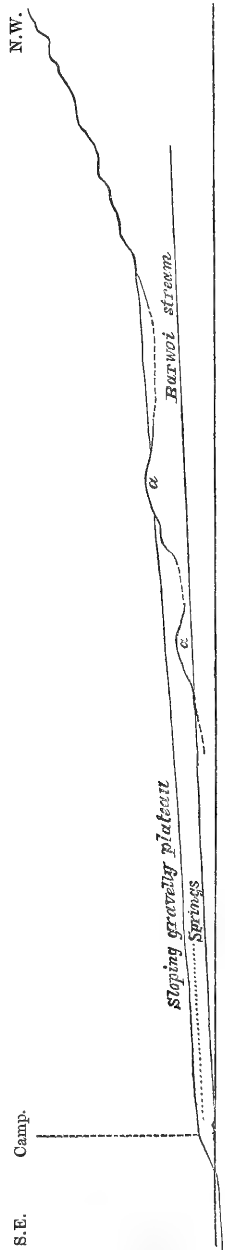


Fig. 12.—*Section across part of Deosai.* (Horizontal scale 2 miles to 1 inch. Vertical scale exaggerated.)



called Deosai. The surface-structure of it must be carefully examined. The plateau, though of a height varying from 12,000 to 13,000 feet above the sea, is not of those from which the ground falls on all sides; on the contrary, it is entirely surrounded, except at the spot where its drainage finds a way out by the Shigar river, by high mountains. The mountains form a ring, irregular but still of a general circular form; the diameter of this ring from crest to crest of the ridges is about 25 miles. The mountains make a rugged serrated barrier with a height of from 16,000 to 17,000 feet. There are few low depressions in them; on the west side there are one or two about 14,000 feet, while to get out of the circle to the north-east, in the way that is the highroad from Kashmir to Skārdū, one has to cross a pass of 15,700 feet. The face of the mountains is divided into steep-faced hollows, bounded by long projecting spurs; these spurs as they slope towards the centre become rounded, and show signs of ice-moulding. Further still they die down, and in continuation of the line of them we find strips of plateaux of detrital matter separated by valleys that originated in the hollows of the mountain-ridge. It is these plateaux and the flat valleys between them that constitute the plain of Deosai. The diameter of the ring being 25 miles, an inner concentric circle of a diameter of 15 miles will, roughly speaking, include these plains, which have an elevation varying from 12,000 to 13,000 feet, according as we measure a valley or an intermediate plateau, or according as we take measure either near to or away from the mountains. The form and structure of the plateaux can be best illustrated by our taking the one I examined most in detail (that marked on the Great-Trigonometrical-Survey Map *Shamoskith Plains*), what I saw of the rest making me think them to correspond closely with this. The diagram fig. 12 gives a sectional view of it, as observed from the valley next it on the north-east (named Barwoi). The plateau has a regular slope of 4° from the mountain-spurs for 8 or 10 miles; it is composed of stones, mostly half-rounded, some well rounded, a few angular. In size they are commonly a foot or two in diameter, and from that down to the size of one's fist; but some masses I measured are as much as 6 feet, 15 feet, and even 30 feet across. They are mostly derived from granitic rocks; but some are of greenstone, and some of a metamorphosed slaty rock. On the side of the plateau I observed a line of springs, or oozing of water, at perhaps 100 feet down from it, and continuing with great regularity for a mile or two, with a dip of 3°, being rather less than the slope of the plateau. It seems to denote stratification of the substance, as being due to a more clayey bed. The height of the plateau above the side valley varied from 500 feet near the mountains to 300 feet further out, the slope of the present stream-bed being less than that of the high plain. It will be seen that the gravel laps round some isolated rocks, which are ice-moulded even above the level of it.

Beyond the valley we have been observing from, between it and the next to the north-east (called Lālpāni), there is a low-level

plateau only about 30 feet above the streams, or rising but little more than that; it is formed of débris similar to that of Shamoskith; the width of it was about two miles. These plateaux jutted, so to say, from the spurs of the mountains on the northern or north-western part of the ring; from the south-eastern part I observed a quite similar plateau extending out in a long line at a level corresponding generally to that of the higher one described.

The detrital matter that makes the substance of these plateaux, I look on as originating in a similar way to that of the plains of Drās and Kargil; I regard it as a high-level alluvium of the converging streams that spring from the ring of mountains. The whole space must have been filled to the level of the highest plateaux: these, however, we have seen to slope from the mountains; and there was probably at one time a general converging slope from most parts of the mountain-ring to where the waters collected for their exit. The accumulation of alluvium probably occurred during the period when the glaciers existed which moulded the rocks which here rise from the alluvial plateaux, the glaciers themselves, may be, rising on the alluvium as it was formed: the large blocks met with here and there towards the centre may have been carried by river-ice; for I do not observe distinct moraines so far out from the mountains, though it is possible that the glaciers once extended there, and that most of the signs of their presence have been hidden by the alluvial matter. There seems to me no evidence of this ring of mountains having enclosed a lake; the deposits are by no means of a lacustrine character. It is quite consistent with the facts observed in other parts of the country that these deposits should have been formed by the streams to the thickness of 500 ft. (and it may be more), and at that time have been continuous with the alluvium of the Drās and Indus rivers, which also were at a high level. The lower plateaux and the valleys now occupied by streams were then denuded at the time of the general denuding of the alluvium all over this country—of the last lowering of the river-beds. On this theory, the Deosai plains, which are now a waste of dry gravelly ground in broken plateaux surrounded by a dark ring of mountains, were formerly one wide stony flat traversed everywhere by streams which flowed from glaciers that sprang from a circle of mountains so snow-covered that the rock was hardly seen.

I wish now to put on record a few facts observed in a part of the country further to the north-west, reaching to the extreme point in that direction accessible to Europeans; I refer to the Astor (or Hasora) and the Gilgit valleys, on the south and north respectively of the Indus river, near where it makes its great bend.

In the higher part of both branches of the Astor valley there does not seem to have been any late lowering of the stream-bed, the fans of the side streams are not cut down into; but lower down we meet with signs of the present level being far below where the stream once flowed. South of Gabri Dās, or Gabri plain, round stones of alluvial origin are seen on the hill-side some 400 ft. above

the stream. A few miles below that the Choi stream comes in on the left bank from the glaciers that form on the great Nanga Parbat; a little way up this stream is seen a clear section of a deposit that must be partly of glacial origin: on the right bank of it the river-cliff shows 250 ft. of an irregular accumulation of material, large blocks occurring in the finer stuff, while on the left bank at the same level are well-stratified pebble beds; on the plain above the irregular deposit are small mounds which are clearly of moraine origin; we must therefore put these down to the combined action of the old glacier and the stream. Near Gurikot*, at the junction of the two branches of the Astor valley, there is alluvium with well-rounded pebbles one or two hundred feet above the river, forming a narrow plateau. At Astor itself, there is a sloping plateau coming out of the valley of the side stream. Sections through it show a great accumulation of material that must have been deposited partly by the glacier itself (which still exists high up that valley), and partly by the streams: from the remains of gravel here and there I concluded that the main stream had formerly flowed on its alluvium at a level of 600 or 700 feet above the present one. Further back, behind Astor, there is a curious accumulation of débris, in curved beds attached to the mountain-side, which may be the remnants of higher-level fans and taluses; but their origin was not clear to me; there was, indeed, separate evidence of there having been an older plateau, due to the side stream, some 200 feet above the present one.

In the Gilgit valley, besides higher relics of former lakes, there are the usual remnants of river alluvium seen a few hundred feet above the present stream; near Gilgit Fort they are at a level of 300 feet above; and at different spots as far as Gākūj, which is the highest point I went to, there are similar evidences.

Summary.—To sum up, to review the different kinds of deposit and to get what we can of history out of all these details of their occurrence, will not take us long.

The taluses do not tell a tale of any particular epoch. They are always being formed, and when formed may stay for ages; but when once a talus is attacked from below, as by the stream that eats its way to the foot of it, it quickly goes; the material is unable to stand at any but the original slope, and so is carried away to the next stage of deposit.

Fans and alluvium are better records; the facts about them that I have given afford weighty proof of these three states having succeeded one another over all the country we have dealt with:—first a cutting of the ravines to something near their present depth; next a filling of them with material brought down by the streams to such depths as 200, 300, and even 600 or 700 feet, and this filling, though to varying depths, being general; lastly a cutting down of the streams, through the alluvium they had formerly accumulated, to a depth sometimes less, but perhaps on the whole more, than they had originally reached.

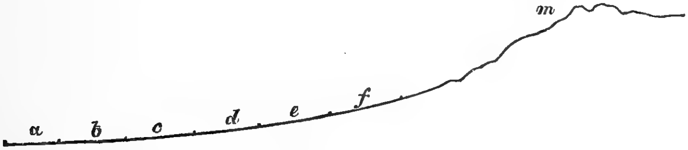
* There is another Gurikot in the Gurez valley, with which this place must not be confounded.

The problem that now presents itself is to account for the streams and rivers being at one time denuders, at another accumulators, and at a third denuders again,—in other words, to discover why these streams shall at one time lower their beds, cutting down through the rock, at another raise them by depositing alluvium and rising upon it, and at last again lower their beds by cutting down through that alluvium.

In any river, taking it in the round of a year, there is sure to be, at all parts of its length, a downward movement of material. If at any particular spot there is a greater amount of material brought from above than is carried off down, accumulation occurs there; it need not be that more is carried down past that spot, but at all events more arrives than is carried away. *Vice versâ*, if at any particular point in the river's course the amount of material carried away is greater than that supplied from above, then there is denudation or lowering of the river-bed; in this case the supply from above is not necessarily, nor probably, cut off, but it is less than what is carried away.

In the diagram (fig. 13), let us take *a*, *b*, *c*, *d*, *e* and *f* to be portions of the course of a stream, in each of which the action may

Fig. 13.—*Diagram illustrating river-action in the deposition and denudation of alluvium.*



be considered equable for that length; and let the part marked *m* represent the sources of the river in the mountains, where loosening and transportation of material takes place, but not the formation of alluvium; then let us for a first case suppose that alluvium was accumulating in the spaces *a* to *f*; it must follow that the material moved through *a* is less than the material supplied to *a*; but the material supplied to *a* equals the material moved through *b*; therefore the material moved through *a* is less than the material moved through *b*. For the same reason the material moved through *b* is less than that moved through *c*, and so on. Lastly, the material moved through *f* is less than that supplied to *f*; or, in other words, the material moved through *f* is less than that which is supplied to it from the region of waste. That is to say, there is a greater amount of material moved as one goes up stream, and the amount supplied from the rocks is greater than that which is moved through the alluvial district.

On the contrary supposition, which corresponds to the last state of things that has occurred, of the stream deepening its channel, cutting down through its alluvium, the material moved through *a* is greater than that supplied to *a*; but the material supplied to *a* equals that

moved through *b*; therefore the material moved through *a* is greater than that moved through *b*, and that moved through *b* is greater than what is moved through *c*, and so on; and, lastly, the material moved through *f* is greater than that supplied from *m*. So that here, as one goes up stream, the matter moved diminishes in quantity, and there is less supplied from the rocks than what is carried on in the alluvial district.

Thus it appears that the change from accumulation to denudation or from denudation to accumulation in a river-bed corresponds to a change in the relations between the carrying-power of the water, and the disintegrating-power of the elements. That is to say:—

When an accumulator becomes a denuder, the carrying-power of the water has increased, or the disintegrating action has decreased, or both; and

When a denuder becomes an accumulator, the carrying-power of the water has decreased, or the disintegrating action has increased, or both.

Now the great agent for disjointing and disintegrating rocks, more especially hard rocks, such as occupy by far the greater part of the Indus valley, is well-known to be frost; and as we know of a period of more severe frost (the glacial period, evidenced in this country too by marks of extension of the glaciers), it is fair for us to connect such changes as the above with the increase and decrease of cold.

Whether in that period there was any variation in the transporting-power of the streams, I do not at present see a way to determine; the material is, as a whole, of the size that is even now brought down by the streams, taking the spring and the occasional floods into account; nor is it clear to me whether, the amount of precipitation remaining the same, snow and ice periodically melting, or rain would have the greater transporting power.

Leaving then out of our consideration, as neutral, the element of transporting-power, we see at one time an increase of cold, at another a diminishing cold to account for the changing ratio between the amount of material supplied from the rocks, and that carried down by the streams.

The intense cold of the glacial period brought about a greater disintegration of the rocks; this caused the streams to be accumulators. From the lessening of the frost-power at the close of that period, the supply from above of disintegrated material so far diminished as to allow of the streams both carrying down what was then being disintegrated and eating into the alluvium that had before been formed.

The conclusion then is that the greater deposits of alluvium were made at some part of the glacial period, and that the denudation of them occurred, or began, at the close of that period, when the lessening cold diminished the rate of waste of the rocks.

To corroborate this I may recall how many instances occurred in the description of the old alluvium where there were special phenomena (as the waved strata, the lapping round moraines, and others)

which were to be accounted for by the presence of glaciers below where glaciers now exist, at the time of the formation of the deposits.

Discussion.

Mr. Sowerby confirmed the observations of the author, and said that the phenomena described by him are not confined to the valley of the Indus, but that they occur in other parts of India.

Mr. Blanford remarked that the peculiarity of the region of High Asia is the enormous amount of alluvial deposits—enormous both as regards their thickness and the area they occupy. This peculiarity is rendered the more striking as the deposits are not concealed by vegetation. He remarked upon the absence of stratification in the fan-shaped and other deposits and at the mouths of streams. He expressed himself not quite satisfied that glaciers were the cause of the contorted beds referred to by Mr. Drew. The accumulation of great masses of deposits 700–800 feet thick he thought might be due to the damming up of the streams by landslips; and he stated that he had seen accumulations thus formed extending to 200 feet in thickness.

Mr. Clifton Ward stated that he had frequently found it difficult to distinguish the deposits at the mouths of streams from true alluvial beds.

Prof. Ramsay remarked that some of the phenomena described by Mr. Drew were to be observed elsewhere than in the district where his observations had been made, and referred to examples both in this country and on the continent of North America.

Mr. Drew briefly replied.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

June 11, 1873.

The following communications were read:—

1. *On the* Nature *and* Probable Origin *of the* Superficial Deposits *in the* Valleys *and* Deserts *of* Central Persia. By W. T. Blanford, Esq., Assoc. Royal School of Mines, F.G.S., C.M.Z.S., Deputy-Sup. Geological Survey of India.

Large Area covered by Superficial Deposits.—Deposits of large and small pebbles, gravel, clay, and sand, of geologically recent origin, and very often of thickness sufficient to conceal all older formations, cover an enormous area in Persia*; probably more than one half of the surface of the country is occupied by them, whilst both their nature and their extent are rendered conspicuous by the general want of vegetation. This abundance of what, for want of a better term, I call superficial deposits, appears at first sight more remarkable, because of the general absence of rivers in Persia, and the small rainfall. So far as I can judge from description, the greater part of Central Asia much resembles Persia in its physical characters; and throughout Turkestán, Afghanistán, and Tibet there is the same

* Some of these great gravel deposits are noticed by Loftus, Quart. Journ. Geol. Soc. vol. xi. p. 252; but his researches were chiefly confined to a part of the country in which such formations are probably less extensive than in the regions traversed by myself.

aridity, small rainfall, absence or scarcity of rivers, and paucity of cultivated land, combined with the same recurrence of broad desert plains surrounded by barren mountains.

Physical Geography and Rainfall of Persia.—But an imperfect idea of the physical geography of Persia can be obtained from maps. The country consists of a great plateau from 1200 to 3000 feet above the sea, or rather of a series of plains of that height, separated by smaller ranges from each other, and divided from the lowlands of Turkestán and the Caspian provinces to the north, the Tigris and Euphrates valleys to the west, Laristán and Balúchistán to the south, and India to the east, by a broad belt of mountainous country, containing within itself wide valleys from 5000 to 8000 feet above the sea. Thus the central plateau consists of a number of basins without any outlets*; and the few streams which run into these lose themselves in salt marshes and sandy plains. From the conformation of the ground, it is evident that the rainfall in the central region must be small, since all damp winds, in converging towards it, are driven up to greater altitudes and compelled to surrender a large portion of their moisture on the outer slopes of the surrounding ranges. Thus it is that the south-western slopes of the hills extending from the neighbourhood of Shiráz along the north-east side of Mesopotamia, and the northern watershed of the Elburz mountains facing the Caspian Sea, are clothed with forest, whilst the inner slopes of the same ranges towards the central plateau are barren. Yet rain and snow, frequently in heavy falls, are by no means unknown in winter in Central Persia; thus in 1871–72 the famine at Tehrán, Isfahán, Káshán, and other towns was greatly aggravated, if not to a considerable extent caused, by all communications with the surrounding country being cut off by heavy snow-drifts. Káshán is but 3000 feet above the sea, and it is on the edge of the great desert of North-western Persia; yet the quantity of snow was sufficient for people to be lost in it. The rainfall, however, is, as a rule, confined to the winter months. There is thus in Persia one element of rapid and effective denudation present, viz. the concentration of the rainfall. Another important aid in the work is the occurrence of severe frosts, the winter being excessively cold, even as far south as 30° N. lat.

The paucity of rivers in Persia has been noticed by many travellers in the country; and I can only add, as my own experience, that in a journey from the Indian Ocean at Gwádar, within 200 miles of the Indian frontier, to Resht near the Caspian, *viâ* Jálk, Bampúr, Karmán, Shiráz, Isfahán, and Tehrán, I crossed but two streams (that commonly known as the Bandamir, near Persepolis, and the Safed Rúd, which runs into the Caspian near Resht) which are not easily fordable, as a rule, at all seasons; and I do not think that, in the whole journey of upwards of 1500 miles I crossed a dozen streams more than 6 inches in depth. Of course,

* Recent researches render it probable that these plains are by no means so extensive as they are represented on the maps, but that they are much broken up by low ranges of hills. The general surface may be considered a series of very broad valleys, without rivers and without outlets.

many of the streams become impassable torrents after heavy falls of rain, or when snows are melting rapidly; but in general they contain no water at all, or a very small quantity. In many large valleys there are neither streams nor dry stream-beds.

These peculiar features of the meteorology and physical geography of the country are mentioned, because without noting them it is difficult to understand some of the problems presented by the superficial deposits. As I shall endeavour to show, I believe that the condition of some of these deposits is due to the small rainfall.

Desert Plains.—The great plains of Persia have been comparatively but little traversed, all the principal roads passing through the towns and villages on the edges of the deserts. The general surface and character of these plains varies, in all probability, but little throughout. In the smaller plains, and in the larger deserts at a short distance from their margins, the surface usually consists of very fine, pale-coloured, rather sandy earth, which, although barren in general, is fertile wherever irrigation is practised, unless, as is not unfrequently the case, it is strongly impregnated with salts. The actual margins of most plains are stony; but to these I shall revert presently. The surface is often much covered by blown sand, consisting of small grains of quartz and other minerals, of low specific gravity. These sands are, of course, constantly shifting, and cannot be taken into account, the deposits which form the real surface of the country underlying them.

Salt Swamps and Lakes.—I have already referred to the occurrence of salt in the desert soil. Most of the few streams which exist terminate either in salt marshes or salt lakes. Thus the Jaji Rúd* and Kirij, running from the Elburz, one on each side of Tehrán, and other streams coming from the neighbourhood of Kásvin and Hamadán, all terminate in broad tracts of salt swamp on the margin of the great salt desert which separates north-western Persia, or Irák, from north-eastern Persia, or Khorassán. Further south the Zenderúd, which runs through Isfahán, loses itself in a similar swamp between that city and Yezd; and on the road from Karmán to Shiráz, Major St. John and I crossed a salt marsh formed at the termination of a stream draining the south-eastern continuation of the plain in which the Zenderúd runs. The so-called Bandamir of the maps runs into the salt lake of Niriz, and the Shiráz salt lake receives the drainage of the Shiráz plain, the existence of a lake in these localities, instead of a marsh alone, being probably due to the greater rainfall. In dry years these lakes, which are very shallow, nearly disappear, and the greater portion of them become swamps, covered with a thick incrustation of salt. The salt lakes of Van and Uruniah probably resemble those of Niriz and Shiráz. To this apparently general rule amongst rivers entering the Central-Persian plateau, of terminating in a salt swamp or lake, the Helmund river offers a remarkable exception, since the shallow lake or marsh of Sistán, into which it runs, is said to be quite fresh. This lake, like some of the others, dries up to a great extent after

* "Rúd," Persian for a river.

a few rainless seasons; and Sir F. Goldsmid's party in 1872 found that it had entirely disappeared, with the exception of two small pools*.

Slopes of Gravel on the margins of Desert Plains.—The margins of the desert plains have already been described as stony. They usually consist of a long slope composed of gravel and boulders, and with a surface-inclination of from 1° to 3°. Such slopes often extend for a distance of from 5 to 10 miles from the base of the hills bounding the plains, the difference in level between the top and bottom of the incline being frequently from 1000 to 2000 feet, or even more. What proportion of this thickness consists of *detritus* it is impossible to say; but the depth of the deposit must be great, because hills of solid rock but rarely emerge from it. The greater part of such slopes consists of sand and pebbles, the latter more or less angular, and mixed with large blocks, all derived from the adjacent hills. There is, so far as I know, nothing like a beach-deposit in any case. Fragments 2 to 3 feet in diameter are not uncommon, even at a distance of a mile or two from the base of the hills; but I only observed them near places where small streams issue from the higher ranges. At such spots the gravel deposits are naturally very often raised into a fan-shaped slope. Such a phenomenon is common enough in all countries; and so are stony slopes at the bases of steep hills; but the peculiarity of these slopes in Persia consists in their great breadth and in the enormous mass of detrital deposits which they contain.

Slopes of Detritus in Valleys.—From many of the desert plains of Persia valleys of great width extend far into the more hilly regions. These valleys have, along their sides, precisely such long slopes of gravel as I have just described. The presence of a stream in the middle of the valley is by no means constant; but occasionally small rivulets coming from the side run for miles along the slopes without descending to the bottom of the valley, and are finally absorbed by the soil, if not exhausted by being diverted for irrigation.

Instances of Gravel Slopes.—It is as well to describe briefly a few instances† of these remarkable gravel slopes, in order to show their nature. One of the most striking cases noticed was near the town of Bam, in South-east Persia. The town is built at a point where a broad and very straight valley coming from the west-north-west opens on to the desert which stretches to the north of Narmánshir. From the town, which is about 3600 feet‡ above the sea, a very gradual gravel slope leads to the desert plain, the elevation of which near its margin is probably between 2000 and 2500 feet. The

* Goksha Lake, near Erivan, in the Transcaucasian province of Russia, is another example of a freshwater lake without an outlet; and there is a small example of the same kind at Dastárjan, west of Shiráz.

† I hope that the detailed geological observations made during my journey through Persia will hereafter be published by the Indian Government, and I must refer to them for further details of these formations.

‡ The heights given are chiefly from aneroid readings, and are consequently only approximate. The height of Bam is from Major St. John's boiling-point observations.

broad valley already referred to is about 30 miles long, diminishing gradually in breadth from about 20 miles at Bam to 10 miles at its upper extremity, which is at an elevation of about 5500 feet above the sea. The slope at each side of the valley is in places at least 10 miles broad, and inclined at about 2°. In the upper part of the valley there is no stream or stream-bed in the middle; at the time when I marched through it a considerable torrent, fed by melting snows, ran for 20 miles halfway up the side of the lateral slope.

Another good example was seen about twenty miles S.W. of the town of Karmán. Our march lay across a valley running W.N.W. and E.S.E., and about thirteen miles in breadth. On the north side of the valley there is for three miles a regular slope at an angle of about 3°, or rather less; a breadth of about six miles at the bottom of the valley is nearly flat, and consists of a light-coloured sandy alluvium; whilst the gravelly incline on the south of the valley is from four to five miles broad, with a rise of 450 feet; so that the angle of inclination scarcely exceeds 1°.

To take a few examples from better-known parts of Persia, a very fair slope, of small breadth however, exists just south of the city of Isfahán. The main road northwards from Isfahán to Tehrán, from the halting-place at Murchikúr, two marches north of Isfahán, and 5500 feet above the sea, almost as far as Soh, the next halting-place, at an elevation of nearly 8000 feet, a distance of twenty-three miles, passes over one long slope of detritus. There is a very well-marked incline about five miles broad, and with a difference of 1500 feet between the top and base, just south of Kashán, about 100 miles north of Isfahán, and on the edge of the great desert plain which extends nearly to Tehrán. And, lastly, Tehrán itself is on the lower edge of a slope which stretches upwards to the base of the Elburz mountains, and which is ten miles broad, with a rise of about 2000 feet.

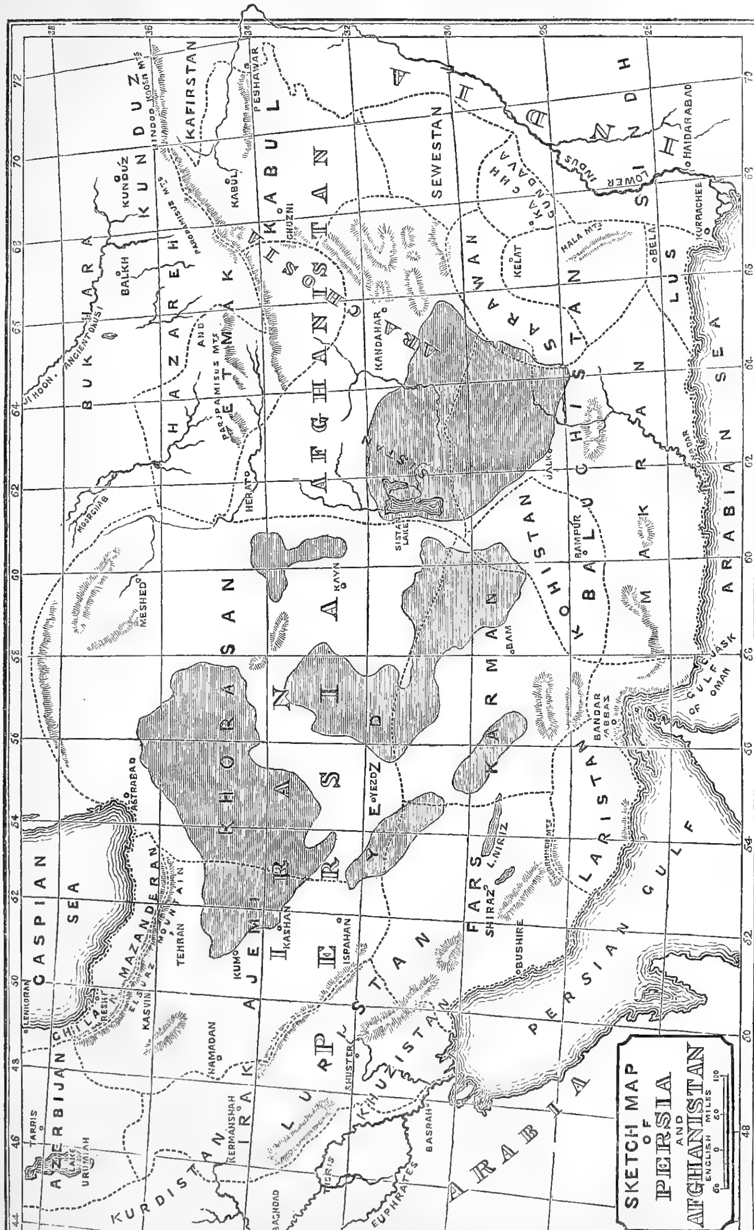
Deposits at higher elevations.—Even at higher elevations than those to which I have hitherto referred, immense accumulations of loose deposits cover the country in many places; and the higher ranges and peaks rise out of them. Thus on the march from Bam to Karmán, the road, between Ragyin and Mohun, ascends in one place to upwards of 9000 feet above the sea. The ascent and descent are extremely gradual, the region traversed consisting of a somewhat broken undulating tract, composed of gravel and clay with boulders, and lying between ranges of limestone and other rocks which rise to an elevation of about 4000 feet above the road. I am somewhat inclined to attribute the higher superficial deposits of this class, in part at least, to glacial action; it is certain that there is a well-marked difference between them and the gravel formations at lower elevations; but, although large blocks, sometimes as much as 2 feet in diameter, were common in the higher deposits, I could find no such angular fragments as usually characterize a glacial boulder-clay, all the pebbles and boulders being more or less rounded. In most cases these deposits are destitute of stratification; but in places they are distinctly bedded, and in one

instance noticed, not far from Karmán, the strata have been much disturbed. Whatever may be the mode of origin of these higher deposits, it is, I think, probable that they must be more ancient than the superficial accumulations of the valleys.

Valleys near Shiráz.—Towards Shiráz the slopes of loose detritus on the sides of valleys are much less extensive, and in places, as in the valley of the Bandamir, above Persepolis, entirely wanting, the flat alluvium of the valley extending to the limestone ranges on each side. This may be due to a former extension of the existing salt lakes far into the valleys of Shiráz and Persepolis, and to the deposition of silt in the lakes in sufficient quantities to conceal any accumulation of detritus near the sides of the valley; but there appeared to me to be a similar deficiency of gravel slopes on the sides of the higher valleys containing running streams, and I am much inclined to believe that their absence is connected with the heavier rainfall. Passing from the Shiráz country northwards towards Isfahán and Tehrán, or eastwards towards Karmán, there is a well-marked increase in the mass of the gravel-deposits and in the extent of country covered by them; at the same time the country to the north and east becomes much more arid from the climate being drier and the rainfall less.

Probable Origin of Gravel accumulations.—This gives a clue to the origin of these immense spreads of recent or subrecent deposits; and in connexion with the last observations I may mention that usually, in Southern Asia, so far as I have seen, it is the drier tracts in which accumulations of gravel attain their greatest dimensions. They are far more extensive in Sind and Balúchistán than in those parts of India in which the rainfall is much greater. Bearing in mind that all accumulations of detrital matter are due to arrest of motion, whether partial or total, in the transporting agent, we can easily understand that the rainfall on the Persian hills may suffice to wash down as far as the sides of the valleys those fragments which, by chemical agency or the action of frost, are loosened from the hill-sides; but when once the momentum given by the steepness of the incline is at an end, the quantity of water drained from the surface is insufficient to transport the débris to a lower level; all that it can do is to leave the detritus in a long slope, the surface of which is arranged by the wash of rain.

Probable Origin of Desert Plains.—But although the above hypothesis may account for the slopes on the sides of the valleys and desert plains, we have yet to explain the origin of the vast deposits which fill the plains themselves; and the only probable explanation appears to be that these extensive basins were formerly lakes, most of them probably brackish or salt, like the Caspian and Aral Seas, lakes of Van, Urumiah, Niriz, &c., the fine soil of the plains consisting of silt deposited in such lakes (see Map, p. 499). On the southern margin of the Sistán desert near Jálk the resemblance to an old sea- or lake-shore is most striking, the lowest spurs of the hills, here formed of vertical shales and sandstones, being rounded in outline, as if worn by the sea, and contrasting strongly with the sharply


SKETCH MAP
OF
PERSIA
AND
AFGHANISTAN
ENGLISH MILES
CASPIAN SEA
PERSIAN GULF
ARABIAN SEA
GULF OF OMAN
ARABIA
KHORASAN
AFGHANISTAN
BELUCHISTAN
KERMAN
FARS
LARISTAN
IRAK AJEMI
MAZANDERAN
AZERBIJAN
KURDISTAN
KHUZISTAN
LURISTAN
SEWESTAN
KABUL
HERAT
KANDAHAR
MESHED
TEHRAN
ISPAHAN
SHIRAZ
YEZD
KASHAN
BUSHIRE
BAGHDAD
BASRAH
KURRACHEE
HAIDARABAD
INDUS
EUPHRATES
TIGRIS

pointed crags of the higher ranges. As all these plains are the lowest parts of the country, no sections are cut through them by torrents, and only their surface can be examined; but from their extent it is palpable that the deposits of which they are composed must be of great thickness; otherwise the older rocks would crop out from beneath more frequently than they do.

But for inland seas and lakes to have occupied the interior of Persia, and for large deposits to have formed in them, it is evident that the climate must have been much damper than at present. In recent times the rainfall has been insufficient to supply water either to fill the basins, or, as we have seen, to wash down the detritus which accumulates at the foot of the hills. Something is doubtless due to increased evaporation, caused by the use of streams for irrigation; but still this alone is insufficient to explain the drying-up of the plains, because even flood-waters no longer reach beyond the margins of the deserts.

From the accounts given by ancient writers it appears highly probable that the population of Persia was much greater, and the cultivated land far more extensive, 2000 years ago than at present; and this may have been due to the country being more fertile in consequence of the rainfall being greater. Some alteration may be due to the extirpation of trees and bushes, the consequent destruction of soil and increased evaporation; but this alone will scarcely account for the change which has taken place.

I cannot but think it probable that a gradual change in the climate of Central Asia generally has taken place from the time when the great plain north of Persia was under water, when the Black, Caspian, and Aral seas were united, and when, as Loftus has shown, the plains of Mesopotamia were a part of the Persian Gulf, this gradual drying-up of the country being thus connected with the elevation of the steppe-region of Central Asia, and of the southern coasts of Persia. To this gradual reduction in the rainfall in modern times is probably to be attributed the circumstance of the Oxus no longer reaching the Caspian, and the diminished volume of that river; for I cannot but suspect that the diversion of the Oxus from the Caspian to the Aral sea in the sixth and again in the sixteenth century* was but the last in a series of changes in the course of a stream which once, in all probability, carried the surplus waters of the Aral Sea to the Caspian. To the same cause is probably due the gradual diminution of the Caspian and Sea of Aral; and hence the disappearance of the lakes which once, I believe, covered no small part of the interior of Persia.

The probability of this theory will be at once seen by supposing a reversal of the process and conceiving the results of a gradual increase, from whatever cause, in the rainfall of Persia. First streams would run in all the valleys, the desert plains would be filled with water and converted into lakes, many of them brackish or salt, whilst the gravels from the higher valleys and the edges of the

* Proc. Roy. Geogr. Soc. 1867, vol. xi. pp. 114–118.

plains would be gradually washed down to the lakes; then a great part of Central Persia would become a vast lake. Finally, as the water increased, the barrier of surrounding mountains would be cut through, probably in several places, and the lakes drained, whilst the country would be converted into a series of ordinary river-basins. All this is precisely the converse of what I believe to have taken place during the desiccation of the country, except that there is no reason for supposing all Central Persia to have been one lake at any time.

Of course the original denudation of the great valleys and basins of Persia must go back to an earlier date than that of the supposed lakes—to a time when these valleys were open to the sea, and were cleared out by running water. Such valleys were probably dammed up by the rise of land in Southern Persia at a time when the rainfall no longer sufficed to keep the channels open. That the elevation of the Southern-Persian mountains is of no high geological antiquity we may infer from the fact that ranges 10,000 feet high consist of nummulitic rocks, that the gypsiferous beds, which are newer than the nummulitics, are found at an elevation of 7000 feet above the sea*, and that the Makrán formations †, which are probably not older than Pliocene, attain almost an equal height; whilst traces of a recent rise of land are common along the southern coasts of Persia and Balúchistán.

Conclusion.—The general results of the facts which I have endeavoured to describe may be briefly summed up. I think it probable that Persia is a country which has undergone a gradual process of change from a moister to a drier climate, simultaneously with the elevation of portions of its surface, resulting in the conversion of old river-valleys into enclosed basins containing large lakes, many of them brackish or salt; then, as the rainfall diminished, the lakes, for the most part, gradually dried up, becoming desert plains; and the process of disintegration amongst the rocks of the hills exceeding the powers of removal, the water which now falls only suffices to wash the loosened rock-fragments from the steeper slopes of the hills into the valleys, not to transport them to the lowest levels of the country. The consequence is that the upper parts of the great valleys are being gradually filled up with coarse gravel-like detritus, just as their lower portions have already been hidden beneath lake-deposits.

In the accompanying map (p. 499) an attempt has been made to delineate roughly some of the lakes which once, I believe, covered a large portion of the Persian plateau. The supposed lake-areas are indicated by the tint. From the want of detailed information the lines laid down are, in most cases, mere approximations. For most of the information embodied in this map, as well as for numerous details scattered through the preceding pages, I am indebted to my friend Major O. B. St. John.

* Loftus, Quart. Journ. Geol. Soc. vol. xi. p. 334, fig. 11.

† Records of Geol. Survey of India, vol. v. p. 43.

Discussion.

Mr. Prestwich could hardly understand how, without a very close examination, it could be ascertained that there were no outlets from the plains which had been mentioned. If by any possibility there were such outlets, great difficulty would arise in accepting the theory. He was not quite satisfied as to the evidence of the thickness of the deposits on the slopes, and inquired as to the presence of organic remains.

Prof. Ramsay had been much struck with the paper, though it was confessedly a rapid sketch of the country. Persia might indeed be regarded as a typical example in an exaggerated form of what was taking place in all dry areas. There are scattered inland salt lakes and large tracts of desert sands, surrounded by immense mountain-ranges, suggestive of areas like those of the Dead Sea, the Caspian, and the Aral, in which the evaporation equalled the supply of water derived from the rainfall, and where in consequence the lakes were salt. In many cases such lakes had become filled with sediment, while others have absolutely ceased to exist from want of rainfall. As to the causes of the formation of the gravels, he agreed with the author that on so large a scale any ordinary river-theory appeared almost inapplicable, and he was content to confess that at present it appeared to him difficult to account for their existence. The history of the Oxus was well known; and its banks had been the scene of constant invasion and disturbance, though they had in early times been occupied by large populations. He thought that in old times the Oxus might have been banked up, like most rivers along which there is an extensive population, and that possibly it was in consequence of the giving way of such banks that its course had been altered. Its condition might, he thought, have been like that of the Po at the present day, the bed of which was now above the neighbouring plains, and which a few years' neglect would divert from its course, so as to cover the surrounding country with ruin.

Mr. Blanford, in reply, stated that from the small plains there were certainly no outlets, and that in all probability there was none also from the great central plain of Persia. This had, indeed, been barometrically surveyed in various directions, and it was found that a large part of its centre was at a lower level than any part of the surrounding country. The slope of gravel at the edges of the deserts usually rested on the lacustrine deposits; and though there was in some cases a difference of 2000 feet between their highest and lowest parts, it was impossible to speak with certainty as to their absolute thickness. He was not aware of any organic remains having been found in the deposits; but they had as yet been but little examined. Though the majority of the lakes were decidedly salt, there were two exceptions—the lake of Goksha and that of Sistán. The greater portion of this latter was now dried up; and though there was no outlet to the remaining portion, it was perfectly fresh. For this circumstance he was not prepared to account; but there appeared to be no doubt on the subject. With regard to the

Oxus, there must have been a time before Central Asia was highly civilized, when the river ran freely through the country unconfined by artificial means; and he thought it possible that at that time its lower part afforded an outlet from the sea of Aral to the Caspian. With a greater rainfall he thought the water of the sea of Aral would find its way along the old course of the Oxus into the Caspian Sea.

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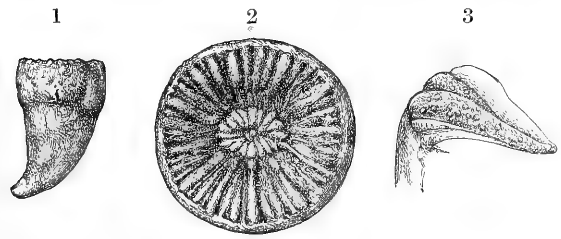
2. *On* Caryophyllia Bredai, Milne-Edwards & Jules Haime, *from the* Red Crag *of* Woodbridge. By P. Martin Duncan, M.B., F.R.S., V.P.G.S., &c.

A specimen of a simple coral has recently been discovered by E. Charlesworth, Esq., F.G.S., in the Red Crag of the Woodbridge district of Suffolk. The form is interesting from its mineral constitution as well as from its adding another species to the coral-fauna of the Crag.

MM. Milne-Edwards and Jules Haime described one of the *Caryophylliæ* of the Maestricht Upper Chalk in their 'Histoire Naturelle des Coralliaires,' vol. ii. page 18, as follows:—The corallum is elongate and much curved; the wall is almost smooth, and is marked with some horizontal ridges; the columella is slightly developed, and sometimes is reduced to a solitary process. There are

Fig. 1.—*Caryophyllia Bredai*, Milne-Edw. & Haime.



1. Side view of the corallum, natural size.
2. The calice, enlarged.
3. A side view of a septum, enlarged, showing the granulations.

four complete cycles of septa, in six systems. The septa of the last cycle are very small; the primaries are thick at their inner end, are larger than the secondaries; and the tertiaries are thin. All are covered with large and projecting granulations. The pali are situated before the secondary septa, and are narrow as well as flexuous.

The newly discovered form appears to be a variety of this Upper Cretaceous species. It differs from the type in being curved at the base and then subturbinate. Moreover the pali are irregularly placed, although the septal number is complete; they are in one

row, and are to be seen before the tertiary and some of the secondary and primary septa.

The specimen is coloured light red; the outside is smooth; and the calice is admirably preserved.

It is probably a *remanié* fossil from the uppermost beds of the Chalk, traces of which still remain in the neighbourhod of Norwich, and which have yielded a fine series of large simple corals*.

Discussion.

Mr. Charlesworth made some comments on the difficulty of ascertaining the exact locality at which Crag fossils were found. He mentioned that in former years he had found Cretaceous fossils in the Crag; but, from the matrix they contained, he had determined them to be derivative. He commented at some length on the liability to erroneous conclusions which might result to palæontology from this intermixture of remains belonging to different periods, and also on the errors which arose from too great a tendency to regard fossils as derivative when, like the cetotolites of the Crag, they actually belonged to the beds in which they occurred. He regarded the coral as derivative.

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3. *On the* Cephalopoda-bed *and the* Oolite Sands *of* Dorset *and part of* Somerset. By James Buckman, Esq., F.L.S., F.G.S.

[Abstract†.]

In this paper the author discussed the true position of certain beds containing abundant remains of Cephalopoda, found in various parts of the Jurassic region of this country, and of the sandy bed underlying the inferior Oolite at Cleeve Hill and other places (called by Prof. Phillips the "Midford Sands"), which has been regarded by most authors as belonging to the Lias. From an investigation of the Cephalopoda-bed in quarries at Bradford Abbas in Dorsetshire, the author comes to the conclusion that it is quite distinct from the Cephalopoda-bed of Gloucestershire, and that it is the representative of the Rubbly Oolite at the top of Leckhampton Hill and Cold Comfort, and of the Gryphite and *Trigonia*-beds of the neighbourhood of Cheltenham. The Gloucestershire Cephalopoda-bed he regards as situated close to the bottom of the Inferior Oolite series; and this is also the position to which he refers the sandy beds above mentioned.

Discussion.

Prof. Duncan, though accepting zones as useful in stratigraphical arrangement, agreed with the author that they could not be used for fixing hard and fast lines of demarcation.

* Described in the Supplement to the Brit. Foss. Corals, Palæontographical Society's Memoirs, vol. xxii.

† The publication of this paper is deferred.

Mr. Evans pointed out that the main question at issue was whether the sandy beds below the Cephalopoda-bed of Bradford Abbas were really the equivalents of those which were found above the analogous bed in Gloucestershire.

Prof. Ramsay regretted the absence of Fellows more especially interested in this question. For himself, he considered it impossible to correlate particular zones over any large area, and thought that the whole series might be regarded as passage-beds, the order of which might vary even within a limited distance.

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4. *On* Cetarthrosaurus Walkeri (Seeley), *an* Ichthyosaurian *from the* Cambridge Upper Greensand. By H. G. Seeley, Esq., F.L.S., F.G.S.

The specimen now described was discovered several years since by J. F. Walker, Esq., M.A., F.G.S., among some fossils gathered at a coprolite-washing in the Upper Greensand, from near the railway-bridge at Ditton, N.E. of Cambridge. Mr. Walker recognized the specific importance of his fossil; and, from a cast, I made a brief note, enrolling the species in the Cambridge Greensand fauna as *Ichthyosaurus Walkeri* *. No other bone presumably referable to the same species is known to have been found; and, as with many of the associated fossils, abrasion has done its work upon this femur in a way to suggest that, like many disfigured recent bones to be picked up on our own shores, these Greensand exuviæ were rolled on a pebbly beach before deposition in the bed of phosphatic nodules at the base of the deposit.

The bones of the extremities of Ichthyosaurians, as was pointed out by Mr. Hawkins, afford excellent characters by which species may be defined; but in this ordinal group no sufficient description of the skeleton has been made to assist comparison of specimens with a type, perhaps because the varieties of structure in the different genera confounded under the name of *Ichthyosaurus* are such as to make a comprehensive diagnosis of the several bones a task of difficulty.

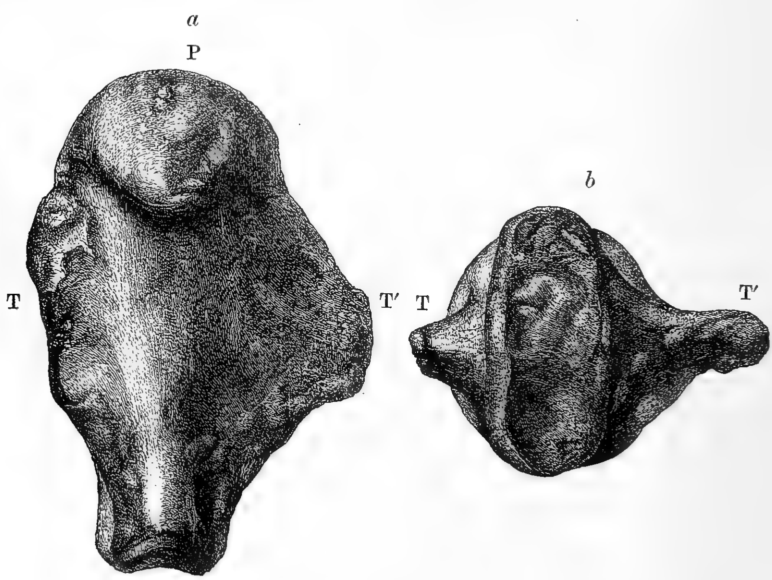
" The femur of *Ichthyosaurus* is a strong short bone, with a small compressed distal end, having its greatest extension at right angles with the greatest width of the head. The distal end shows two or three articular facets for the bones of the foreleg. The proximal end is large, convex, and broad, and sends off on each side a trochanteroid process, which makes the head massive. These processes are rounded laterally, and extend down the short shaft, gradually being obliterated with the increasing compression of its distal end. The outer side of the bone is the flatter; the inner side is made convex by a more or less well-defined, rounded, longitudinal ridge, which, extending from the head of the bone, slightly curves convexly backward, so as to indicate that the greater part of the head lies

* Aves, Ornithosauria, and Reptilia (1869, 8vo), p. 64.

behind a plane at right angles with the distal articulation"*. This description is drawn from the Cretaceous genus of Ichthyosaurians found at Cambridge, and would apply but indifferently to most of the genera from the Lias. This remark holds true in a less degree for the following notes on the similitudes of the Ichthyosaurian femur * :—

"The femur, in shortness and strength, recalls some seals; but in arrangement of parts, the resemblance among mammals is closest to *Ornithorhynchus*, which similarly has lateral trochanters extending the width of the proximal end, though in *Ichthyosaurus* the trochanters are not divided from the rounded articular head." "Among crocodiles the only resemblances are that the articular ends of the bone are compressed, the proximal one rounded and at right angles to the distal end." "The two trochanters at the head of the femur of *Chelydra*, though not so well developed and not opposite to each other, are homologous with those of the head of the femur in *Ichthyosaurus*; but there is no other character in common in the limbs."

Fig. 1.—*Right Femur of* Cetarthrosaurus Walkeri.



a. Underside. *b*. View from the distal end. P. Proximal articulation. T. Anterior trochanter. T′. Posterior trochanter.

With the type thus indicated, *Cetarthrosaurus* is closely comparable. The specimen may be thus described:—

The bone is $2\frac{5}{8}$ inches long, subovate at the proximal end, and a

* MS. Osteology of the Reptilia.

narrow oblong at the distal end. The proximal end is $1\frac{5}{16}$ inch from side to side in the direction of the extension of the distal end, and $1\frac{4}{16}$ inch in the direction at right angles, thus differing essentially from *Ichthyosaurus*; but, as in that genus, the superior outline of the head is somewhat flattened, while the inferior outline is very convex; the head is hemispherically rounded, and so much of the original surface as remains is pitted over with terminal blood-vessels smaller than those of *Plesiosaurus*, and shows indications of the bone having been there sheathed with a thick articular cartilage. The distal end, $1\frac{3}{8}$ inch long and $\frac{5}{8}$ inch wide, is rather wider towards the tibial side, and rather narrower towards the fibula. The distal end shows three articular surfaces—two concave and subquadrate, and a small lunate articulation on its fibular margin. Between the head and the distal end the sides of the bone are concave, rather more so on the fibular than on the ulnar side. On each side of the bone, at right angles to the distal end, is given off an enormously elongated compressed trochanteroid process, which, even as preserved, widen the bone to $1\frac{7}{8}$ inch, while the constricted shaft at right angles measures $\frac{7}{8}$ inch only. On the underside the bone is gently convex from one trochanter to the other; on the superior face a longitudinal convex ridge extends from the distal end towards the head, while the parts on each side of it are made concave by the singular compression of the trochanteroid processes. From the condition of preservation, some difficulty may be felt in deciding how far these processes extended towards the proximal articulation; but as on both sides they are seen to run nearly to the head of the bone, they were probably there given off. The processes may have been of equal lengths, and have measured nearly 3 inches from side to side when perfect, making the bone wider than long.

Some Ichthyosaurians from the Lias in the British Museum show a small trochanteroid process towards the distal end of the bone on the fibular margin, quite distinct from these.

On the subovate form of the head of the bone, and on the development of the lateral trochanters, I base the genus *Cetarthrosaurus*. It may be considered to present a resemblance one degree nearer to the femur of the monotremes than that of *Ichthyosaurus*, a resemblance having its chief interest in other parts of the skeleton.

The name is not intended to indicate cetacean affinities, but merely the general resemblance of the bone to the humerus of a porpoise, which is sufficiently marked to arrest attention.

Discussion.

Sir P. Egerton was inclined to regard the trochanters as vertical rather than as lateral.

Mr. Seeley remarked that in calling the two trochanters lateral, he was guided by the position in which it appeared to him that the limbs were carried during the life of the animal.

June 25, 1873.

Thomas Douglas, Esq., West Lodge, Crook, Darlington; Joseph Mitchell, Jun., Esq., Wasbro' Dale, near Barnsley; Ralph Botley, Esq., of Hindley, near Wigan; Daniel Ruddle, Esq., 60 Delancey Street, N.W.; John Dunning, Esq., C.E., Middlesborough; Thomas Stephens, Esq., M.A., Hobart Town, Tasmania; and James Willis, Esq., Government Inspector of Mines, Durham, were elected Fellows of the Society.

The following communications were read:—

1. *On* six Lake-basins *in* Argyllshire. By his Grace the Duke of Argyll, K.T., D.C.L., F.R.S., President.

The theory of Prof. Ramsay on the origin of lake-basins, and the opposition to it, would do great good if it compelled observers to take note of the exact geological structure of their containing sides. It was as a small contribution to this line of investigation that the author proposed to describe shortly the basins of Loch Fyne and Loch Awe, with some others lying between the two.

The whole country consists entirely of those mica-slates which have been identified by Sir Roderick Murchison as the equivalents of the Lower Silurian beds which, in the typical section across Sutherland, lie between the Cambrian Sandstones on the west and the Old Red Sandstone on the east coast of that county. The strike of these rocks in Argyllshire is generally from N.E. to S.W.; and in the district to be described the dip is to the N.W.

The upper basin of Loch Fyne lies in a long hollow having a general direction parallel to the strike—the northern bank presenting the escarpment and the southern bank the slope side of the strata. Mr. Geikie's geological map of Scotland represents the southern side as composed of the lower, and the northern side as composed of the upper division of the Lower Silurian series. The author has not been able to verify this, nor is he able to say positively that the bed of Loch Fyne occupies a fault. The strata are so like each other that it is difficult to trace faults; and there is a total absence of organic remains. Mining-operations, however, have shown that the beds are full of faults. The shores of Loch Fyne are glaciated on all the projecting points, in such a manner as to indicate the action of floating ice coming from the head of the lake. The block of country between it and Loch Awe is also glaciated in a similar manner, not uniformly, but on the projecting points, up to the highest summit—1700 feet above the level of the sea. The direction from which erratic blocks have come indicates transport from the N.E.

The upper basin of Loch Fyne, of which the greatest depth is 82 fathoms, is sufficiently accounted for when it is seen to occupy a great depression parallel with the general lines of subsidence which the strata have evidently undergone. All the neighbouring valleys are in the same geological position—one side ex-

hibiting the escarpment and the other the slope side of strata, dipping more or less steeply to the N.W. Loch Awe occupies a different position; it lies in a synclinal trough. The slates constituting the base of Ben Cruachan dip steeply into the bed of the lake on the northern side; and the dip of the rocks into the same basin is almost equally steep on the southern side. The islands in the middle of the lake exhibit vertical strata. The lake finds its exit through a gap at the foot of Ben Cruachan—a gap which marks a great structural break or displacement. The eastern side of this gap is formed by the steep sides of Ben Cruachan, rising to a summit 3600 feet above the sea; whilst the western side is formed by the broken escarpment of beds dipping at a wholly different angle, and forming the boundary of a large tract of country of much lower elevation than the mountainous district which terminates in Ben Cruachan. The bed of Loch Awe, therefore, lies in a hollow or basin which is sufficiently accounted for by structural causes; and where these exist so obvious and so sufficient, it would be unreasonable to account for that basin by the denuding agency of ice. Where great subsidences of strata have undoubtedly taken place, it is not reasonable to suppose that such movements would stop at a particular level; and every depression deeper than others would naturally become a lake-basin.

Between Loch Fyne and Loch Awe a series of hilly ridges are composed of slates with associated granites, which seem to have burst along the lines of bedding when the slates fell in, those lines being the lines of least resistance. These hills are full of small lake-basins; and these are generally of a character which seemed to the author to be incompatible with the theory that they were excavated by glaciers, or by ice in any form. He mentioned three, of which the first was Loch Leckan. This lake is about a mile long; it lies in a hollow between two granitic ridges, which, however, are of small elevation. At one point this little lake is 18 fathoms deep. Although the upper part of the basin is in granite, the lower part of it is probably in the slates, since a quartzite bed appears on the shore at the upper end. There are no marks of glaciation on these beds, though of a character well fitted to retain them. There is no hill near which could form the gathering-ground of a glacier capable of doing such excavating work; and the difficulty of attributing this basin to ice-action is increased by the position of the second of these small lake-basins, namely Loch-na-Craig. This lake is separated from Loch Leckan only by a very narrow ridge: it is 9 fathoms deep, of a circular form; and its level is about 150 feet above Loch Leckan. If this lake-basin had been due to any powerful abrading agent capable of digging such a hole in granite, it is impossible to conceive how such agent could have left the narrow dividing ridge standing, which separates it from the lower basin of Loch Leckan. There is nothing to indicate that this deep little hole lay in the route of any conceivable glacier; and its position and character are, if possible, still less capable of being reconciled with the action of a general ice-sheet.

Two other small lake-basins in the same immediate neighbourhood are differently situated, yet also in positions which make it impossible to attribute them to ice. One is called Loch Nanum, the other Loch Shalaga. They are both on the very tops of granitic hills, one of them occupying the summit-level between Loch Awe and Loch Fyne. These are comparatively shallow basins, simply depressions in the granite, with low round knolls forming the banks. These likewise are not in the path of any glacier, and they are in positions in which it is difficult to conceive that ice of any kind could have employed itself in digging holes.

The last lake mentioned was a very peculiar one, called the Dhu Loch. It lies in the valley near Inverary called Glen Shira, and is separated from Loch Fyne by a mass of gravel filling up the mouth of the valley. It is exactly on the level of half-tide, so that at high-water Loch Fyne flows into the lake and makes the water brackish. This lake is a depression in detrital matter, with which the lower part of the valley and the lake are being rapidly filled. This is a case, and the only case in the district, where, in the author's opinion, the basin might be accounted for by glacier-action. It is just such a hollow as might possibly be formed by the weight and motion of a glacier coming down the valley from Ben Buie, which lies at the head of it; and the semicircular form which the barrier of gravel has assumed, on its inward face, suggests the idea of the action of the sea beating up against the point or nose of a protruding glacier. It thus appears that of six lake-basins, large and small, near Inverary, only one is marked by conditions which seem to render it at all probable, or even possible, that the formation has been due to the action of ice.

Discussion.

Prof. Ramsay dissented from those parts of His Grace's remarks which might lead the hearers to suppose that he had attributed all valleys and lake-basins, without exception, to glacial action. On the contrary, he had always maintained that in many instances original valleys were due to various agencies, both of superficial denudation and of internal disturbance, and acting at all periods of the earth's existence. These earlier inequalities had often indeed received their final configuration from the action of ice; and it was only to certain lake-basins that he assigned a purely glacial origin.

He disclaimed many of the ideas popularly attributed to him, regarding them as utterly irreconcilable with the phenomena of nature. As to the sides of the basins, nowhere had he seen a case in which he could regard the existence of a lake as merely due to a fracture of the rocks. In the Highlands of Scotland it was well known that most of the contortions of the rocks had taken place before the deposition of the Old Red Sandstone. He wished to know whether during the ages that had passed since that time all atmospheric agencies had been suspended. On the contrary, their operation had been such that thousands and thousands of feet of strata had by their means been removed. Nowhere was this prin-

ciple more evident than in considering the structure of the carboniferous area of the Mendip Hills, where enormous denudation had taken place long before the New Red Sandstone was deposited. How then could we ignore this operation in other parts of the country? As to faults, he submitted that their existence must be proved rather than assumed. Did they exist, they were not gaping fractures, but closed; and he regarded it as physically impossible for such hollows as those in which the lakes were found to be due to such causes. Even if fractures existed, they could only constitute lines of weakness, along which denuding agents might more readily work. As to the lakes on the summits of ridges, he would not pretend to account for what he had not seen; but he cited similar lakes on the Grimsel, which presented similar phenomena, and which he regarded as undoubtedly due to glacier action. Even on the top of *roches moutonnées* such basins were found; and though he might not know the exact circumstances under which they were formed, they were undoubtedly due to ice-action. If in Switzerland and other glaciated countries of the present day we find the configuration of the country presenting similar phenomena to those of Scotland, he considered that there was ample ground for attributing both to the same cause, and there was no need of invoking other causes. It was moreover to be borne in mind that though similar contorted gneissose rocks to those of Scotland occurred in several other countries, it was only in those which had been glaciated that such numerous lake-basins were to be seen.

The Duke of Argyll, in reply, agreed with Prof. Ramsay that it was not in all cases that the lake-basins were due to disturbance of the rocks; and indeed in some of the most contorted districts lakes were rarely present. All his contention was that whatever may have been the denuding agent, it was not in all cases ice.

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2. Description *of the* Skull *of a* Dentigerous Bird (Odontopteryx* toliapicus, Ow.) *from the* London Clay *of* Sheppey. By Professor Owen, F.R.S., F.G.S., &c.

[Plates XVI. & XVII.]

Amongst the additions to appear in the second edition of my 'British Fossil Mammals and Birds' I have anticipated the descriptions of certain species, as in the case of the gigantic Eocene bird, equalling in size the larger New-Zealand Moas†. The still more remarkable Ornitholite, also from Sheppey, which I am now about to describe, has stronger claims to be made known, without delay, on account of the transitional character which it manifests to the Pterosaurian order.

The fossil consists of a large portion of the skull, which, when the specimen was received in the British Museum, was more or less imbedded in the London Clay; the clearing out of the matrix by the

* Gr. ὀδούς, tooth; πτέρυξ, wing of bird.
† *Dasornis londinensis*, Trans. Zool. Soc. vol. vii. p. 145, pl. 16.

careful and skilful hands of Mr. Davies, Senior Attendant in the "Geological Department," brought to light the tooth-like processes of the alveolar borders of both upper and lower jaws, to which the uniqueness of this Eocene fossil is due; but the distinctive cranial characters of the warm-blooded feathered vertebrate are unmistakable.

The well-developed brain, expanding transversely in its posteriorly placed box (Pl. XVI. figs. 1–4, 3, 7, 11), making the base of a long cranial cone gradually tapering forward, the capacious lateral orbits (*ib.* figs. 1, 2, 4, o, o), and the single hemispheroid condyle (*ib.* fig. 3, 1) are avian: the large and long, freely articulated, dependent tympanic bone (*ib.* figs. 1, 2, 3, 28), the slender, straight and styliform zygomatic bar (*ib.* figs. 1 & 2, 26) received behind into the articular cup of the tympanic (*ib.* figs. 1 & 3, *h*)—all the modifications, in short, that relate to the free and characteristic movements of the beak—are likewise here present.

Nothing in the fossil, at first apparent, could have led to a suspicion of the significant and well-marked modification of the mandibles which has suggested the generic name I have proposed for this extinct Eocene bird.

The occipital region (Pl. XVI. fig. 3) is broader than it is high; the occipital foramen (*ib.* *m*) partakes of the same proportion; the transverse diameter also exceeds in the condyle (*ib.* 1), of which hemisphere the upper part is truncate. The upper border of the foramen, through the posterior swelling of the cerebellum, slightly overhangs the condyle. The cerebellar protuberance (*ib.* 3) seems to have had a vertical median ridge, as it shows the broken or worn base of such a prominence. On each side of the cerebellar protuberance the occipital surface is smooth and moderately concave across; it is, in a less degree, convex vertically, until it bends in below to the upper border of the occipital foramen. The beginning of the subvertical exoccipital prominence (*ib.* 2), passing obliquely from near the side of the foramen magnum to the paroccipital wall (fig. 1, 4) of the tympanic cavity, is preserved; but the paroccipital itself is broken away. The upper transverse occipital ridge, low and linear, arches outward from the top of the vertical ridge (fig. 3, *x*, *x*) on each side down to the broken base of the paroccipital.

The depth (vertical diameter) of the occiput to the lower border of the condyle is $10\frac{1}{2}$ lines (0·022 m.), to the upper border of the occipital foramen $6\frac{1}{2}$ lines (0·015 m.); the extreme breadth (transverse diameter) of the occiput is 1 inch 3 lines (0·032 m.); the transverse diameter of the occipital foramen is 4 lines (0·008 m.).

The portion of the atlas (Pl. XVI. fig. 3, *v*) preserved, as dislocated from the condyle below the foramen magnum, closely conforms to the avian type of that vertebra.

The parietal region (*ib.* figs. 1, 2, 3, 4, 7) slightly rises as it advances from the superoccipital ridge to the interval between the postorbitals, when the frontal surface passes forward with a slight convex curve to between the large orbits, and gradually sinks as it goes straight to the transverse fronto-nasal suture (*ib.* fig. 4, *f*, *n*). The

parietal region (*ib.* 7) is smooth, transversely arched, and feebly impressed by the upper part of the crotaphyte fossa (figs. 1 & 2, *s*) opposite the middle of the occipital region.

The breadth of the cranium here is 1 inch 9 lines (0·045 m.); the length from the lateral occipital ridge to the hind margin of the orbit is 7½ lines (0·016 m.). If a transversely curved fracture of the upper part of the cranium had coincided with a coronal (fronto-parietal) harmonia, the fore and aft extent of the coalesced parietals at their median (sagittal) suture would be 5½ lines (0·012 m.). It is singular that a second fracture of the cranial roof should have commenced behind where the interfrontal suture terminated, and have extended forward to opposite the middle of the orbit; but this fracture soon quits the median line and inclines to the right; it is also complicated with a shorter posterior fracture starting from the transverse one simulating the coronal suture, but which curves unsymmetrically more forward on the left than on the right side.

The frontals, moderately convex transversely at their back part, become flat and then slightly concave in that direction as far as the fronto-nasal suture (Pl. XVI. fig. 4, 11,*f*, *n*); this is not a fracture, or but partially so at its outer ends.

The length of the frontal part of the cranium is 2 inches (0·050 m.); the least breadth of the interorbital tract is nearly 6 lines (0·012 m.); the extent of the frontal suture is 9 lines (0·020 m.). The antorbital process of the lacrymal (fig. 2, 73) is less mutilated on the left side of the fossil, which gives an appreciable idea of its size and shape.

Both fore and hind boundaries of the orbits (Pl. XVI. figs. 1, 2, 4, *o*) are partially broken away; but the antero-posterior diameter of those cavities seems to have been 1 inch 2 lines (0·030 m.); the vertical diameter is 1 inch 1 line (0·027 m.); they are of an oval form, with the small end forward. There is no trace of a depression for a superorbital gland; the upper border of the eye-chamber is thin, not to say sharp.

In the basal portion of the upper mandible here preserved (figs. 1, 2, 4, 15, 21, 22) there is no remaining trace of suture to mark the boundaries of the nasal, premaxillary, or maxillary bones.

An upper tract (fig. 4, 15), flattened at its hind part, is defined by two obtuse linear risings converging from the ends of the fronto-nasal suture rapidly, then bending forward, broadening and converging gradually till lost in a median transverse convex ridge or tract (22), 2 lines (0·004 m.) broad at the anterior fracture; the breadth of this mid tract, where flat, at the beginning of the lines of minor convergence, is 4 lines (0·008 m.).

The sides of the base of the upper mandible slope outward as they descend to a longitudinal groove (figs. 1 & 2, *g*), with a slight curve concave downward, below which the upper jaw-bone descends vertically to the alveolar border.

The extent, lengthwise, of the upper beak-bone here preserved is, on the left side (fig. 2), from the end of the fronto-nasal suture, 1 inch 6 lines (0·037 m.), on the right side (fig. 1) 1 inch 1 line (0·027 m.); the vertical diameter of the base is 9 lines (0·020 m.),

at the fractured end $7\frac{1}{2}$ lines (0·017 m.); the transverse diameter of the base, at the parallel of the fronto-nasal suture and at the alveolar borders, is 1 inch (0·025 m.), at the fractured end 9 lines (0·018 m.).

From the gradual loss of dimensions in the basal extent of the bony upper mandible here preserved, I estimate that the length of the beak from the fronto-nasal suture must have exceeded that (2 inches 5 lines) of the skull behind such suture, and that the total length of skull of *Odontopteryx* could not have been less than between 5 and 6 inches (see 'restoration' proposed in Pl. XVI. figs. 7 & 8). There is no trace of external nostril in the preserved extent (1 inch) of the upper beak-bone; a notch (Pl. XVI. fig. 2, *n*) at the fractured fore border, left side, may be part of such; but it is narrow, and is like a similar notch and obvious fracture situated further back, on the right side of the fossil. The malar zygoma (Pl. XVI. figs. 1, 2, 4, 26) is continued from the sublacrymal part (fig. 2, 73) of the base of the beak above the longitudinal lateral groove; below that groove the upper jaw appears to have terminated behind in a short free point (fig. 2, 21); but such, if it existed, has been broken away on both sides. The groove reappears on the zygoma, and indents the middle of its outer surface; the least vertical diameter, beneath the middle of the orbit, of the zygoma, is $2\frac{1}{2}$ lines (0·004$\frac{1}{2}$ m.); toward the fore part of the orbit this diameter gradually augments; but the bone is broken away at the junction with the lacrymal, together with the lower part of that bone (fig. 2, 73); its conjunction and seeming continuation with the base of the upper beak-bone, above the longitudinal groove, is preserved. From this part, on the parallel of the fronto-nasal suture, an extent of 1 inch 5 lines (0·036 m.) of the left zygoma is preserved, and nearly as much of the right zygoma; both appendages diverge with a slight downward slope toward the zygomatic cup (*h*) at the outer border of the tympanic (28) above its mandibular condyles.

The tympanic is preserved in its natural articulation with the mastoid on the right side (Pl. XVI. figs. 1 & 3, 28): it is $9\frac{1}{2}$ lines in length (0·020 m.), 3 lines (0·006 m.) in least breadth, $7\frac{1}{2}$ lines (0·015 m.) in greatest breadth at the lower articular end, including the zygomatic cup (*ib. h*). Of the two condyles there, the outer one (fig. 3, 28 *i*) is a transversely extended convexity, the inner one (*ib. k*) is a narrower ridge-like convexity directed obliquely from behind inward and forward, where it slightly expands; a transversely concave groove or channel, in a similar oblique course, divides the condyles. A groove of a line breadth divides the outer condyle from the zygomatic (tympano-squamosal) cup (*ib. h*). The shaft of the tympanic is triedral, with one margin slightly rounded, turned outward, another inward or mesiad (fig. 3 28), and with the anterior and internal sides converging upon, and extended into, the orbital process (fig. 1, *l*). The zygomatic cup is supported on a very short prominence, not produced forward so as to augment the fore and aft diameter of the distal end of the bone, which diameter is uniform and short in comparison with the transverse.

The articular end of each mandibular ramus (Pl. XVI. figs. 1 & 2, 30) is broken away: an impression on the matrix shows the vertical diameter of the ramus (fig. 8, 30), at the joint with the tympanic, to have been $4\frac{1}{2}$ lines (0·009 m.); in advance of this the preserved part rapidly gains depth and gives 8 lines (0·017 m.), where it is parallel (figs. 1, 2, 30, 31) with the fore border of the orbit. Here a fracture or suture runs from below upward and forward to beneath the hind point or end of the upper jaw (fig. 2, 21). If this be a suture, it divides the confluent angular (30), surangular (31), and articular elements from the combined splenial and dentary (fig. 2, 32). The latter element loses depth as it advances; the fore part is obliquely broken away nearly opposite the broken fore part of the upper jaw. The vertical diameter of the mandibular ramus is here reduced to 5 lines (0·010 m.); the portion of ramus preserved on the left side is 2 inches 5 lines (0·060 m.) in length; on the right side a corresponding portion of the ramus is preserved, 2 inches 2 lines in length, but with more of the lower border broken away. The course of what remains of the boundary between the dentary (fig. 1, 32) and hinder part (*ib.* 31) of the ramus corresponds so closely with that of the left ramus (fig. 2) as to add to the probability that it is a retained suture, or a yielding of the ramus along the line of, perhaps, a partially ossified suture.

The upper border of the mandible beneath the zygoma is moderately convex toward the orbit, but not partially produced as a coronoid process; the ramus here is thin transversely in proportion to its depth, its thickness not exceeding 2 lines.

The upper two thirds of the outer surface of this part of the mandible is feebly convex vertically, and is divided by a ridge due to the subsidence of the flat lower third part of the outer surface. The line of this ridge or subsidence slightly ascends to the suture with the dentary. From the part of the suture where such line terminates, a groove (Pl. XVI. fig. 2, *f*) begins, which traverses the outer surface of the dentary almost parallel with the alveolar border, and at 4 or 5 lines below it; the part of the outer surface of the dentary above the groove is rather more prominent than that below the groove.

The outer surface of both upper and lower beak-bones is sculptured by fine, irregular, subreticulate, seemingly vascular, linear impressions and foramina.

The alveolar border of the preserved hind part of the upper jaw-bone, an inch in extent on the right side (Pl. XVI. fig. 1). is produced into nine tooth-shaped processes, conical, subcompressed, sharp-pointed, slightly inclined forward. A view of this part of the skull, twice the natural size, is given in fig. 5. The hindmost tooth preserved is but a quarter of a line long, the next is about half a line in length, the third in advance is a little longer, the fourth a little shorter; the fifth (*ib. ib. a*) suddenly increases to a cone or triangle, $2\frac{1}{2}$ lines along its longer (hinder) side, 2 lines along its shorter (fore) side, and nearly as long across the base, which is confluent with the jaw. The alveolar border swells slightly where it forms

the dental base; the outer side of the tooth is sculptured like the rest of the bone, but in a less or finer degree (see the magnified view, fig. 5, *a*). At rather less than a line in advance of this tooth is a minute one like the fourth; in advance of this is the base of a larger denticle (*ib. b*), the fracture of which shows a cavity filled by pyritic matrix; and at a line in advance of this is the fractured hollow base of a smaller denticle: these hollows might at first sight be mistaken for sockets.

The alveolar border of the left side of the upper jaw (Pl. XVI. fig. 2, & fig. 6, magnified two diameters), continued further forward than that of the right side, shows, at a part wanting on the right side, a more advanced tooth (*c*), of the same shape as the fifth (*a*) from the hindermost on the right side, but somewhat larger; its apex is more obtuse and seems to have been worn. This tooth is also a direct continuation of the bone, with the osseous sculpturing more feebly marked than on the jaw, the tooth appearing smooth to the naked eye. The bases of two smaller denticles appear in the 3 lines extent of alveolar border in advance of this tooth.

Thus we have evidence of about twelve of the maxillary teeth or tooth-like processes—two large, divided by an interval of about half an inch, the rest small or minute—all compressed, triangular, pointed, arming the hinder inch and a half of the alveolar border on each side of the upper jaw.

This dental character is more distinctly displayed in the corresponding parts of the alveolar border of the lower jaw. On the right side (Pl. XVI. fig. 1), in an extent of 8 lines from the suture of the dentary (32) with the surangular (31), are five denticles (fig. 5, magn. 2 diameters): the hindermost is as minute as the one above; the next is somewhat larger; the third (*d*) is much larger, though not so large as the fifth (*a*) above, behind which the point of the third below projects. The fourth tooth below (counting forwards) is minute, the fifth (*e*) suddenly enlarged, especially in length, to 3 lines, with a breadth of base of 1 line; it is sharp-pointed, directed obliquely upward and forward. These teeth are processes of the bone; and the outward markings are strongest near the apex.

In the left dentary (Pl. XVI. fig. 2 & fig. 6, magn. 2 diams.), along an inch extent of the hind part of the alveolar border, are three of the larger laniariform teeth (*ib. ib. d, e, f*), divided by intervals of from 3 to 4 lines, in which are minute denticles.

The lower laniaries are longer and more slender than the upper ones; they are similarly directed, with their summits slightly inclined forward.

On an estimate of the extent of the dentigerous borders of the jaws at 3 inches, and a conjecture that the larger teeth were continued at the same intervals (as shown in the fossil) to the ends of the restored jaws, there would be ten of these teeth on each side of both upper and lower mandibles; the intervening denticles would be about double that number (see conjectural restoration, fig. 8, Pl. XVI.).

The strictly avian character of the skull, on which this *quasi-*

reptilian one is grafted, shows profitable comparisons to be within the limits of the feathered class. The inference which has been drawn as to the length of the beak leads us first to compare *Odontopteryx* with those birds in which that part also exceeds in length the rest of the skull, which latter portion, bounded in front by the fronto-nasal suture, I shall speak of in the ensuing comparisons as the "cranium."

Such character is exceptional in the *Aves aereæ* and *Aves terrestres* of Nitzsch. The Hornbills, Toucans, a few Crows, certain Woodpeckers, Kingfishers, Cuckoos, Humming-birds, Kivis, Ostriches, manifest it, but with well-marked differential characters pointing to another road, for the closer affinity of which we are in quest.

A beak longer than the cranium is the rule in the *Aves aquaticæ*; but not any of the waders has the external nostrils so remote from the orbits as in *Odontopteryx*. This character of the fossil confines one to the Totipalmates and tubinarial Longipennates; but the Petrels, like the Albatrosses, Gulls, Terns, and Skimmers have other well-marked characters which remove them from the present extinct genus.

Indeed, the absence of the superorbital gland-pit in *Odontopteryx* limits the field of comparison to the Totipalmates and Lamellirostrals, in which, however, the Swan (*Cygnus olor*) and some Geese (*Cereopsis*) and Teal show traces, more or less definite, of the impression of such gland above and behind the rim of the orbit. There is no such trace in the Cormorants, Anhingas, and Gannets; and it is in these fish-eating sea-birds that an extent of upper beak-bone, free from narial vacuities, would be found corresponding with that which is preserved in the Sheppey fossil. But the Totipalmates have not the orbit bounded by a hind wall as in *Odontopteryx*; the superorbital border is abruptly truncate behind by a wide and deep crotaphyte fossa, which in the Cormorant and Gannet ascends so as almost to meet its fellow upon the parietal region of the cranium.

In *Odontopteryx*, the parietal region is broadly and smoothly arched (Pl. XVI. fig. 4, $_7$); and the crotaphyte fossa (Pl. XVI. figs. 1, 2, $_8$), very shallow, commences low down at the side of the arch (fig. 1, $_8$), very little above the level of the foramen magnum. Now this is the character of the fossa in certain *Anatidæ*, the Goose (*Anser palustris*) e. g.; and in this family, also, the orbital wall is continued down the back part of the cavity as in *Odontopteryx*, but is there produced forward as a strong process, which seems not to have existed in the fossil. The hinder half, however, of the external nostril would have appeared in the base of the beak preserved in the fossil, if the bird it represents had partaken of the narial characters of the Lamellirostrals.

In most of these water-birds the coronoid border of the mandible is raised into a definable process; and where, as in *Mergus*, this is not the case, the outstanding tubercle is present, of which there is no trace in *Odontopteryx*, as there is none in the Totipalmates.

The hind half of the mandibular ramus resembles in its depth and thinness that part of the lower jaw of the Lamellirostrals more

than it does the same part in the Totipalmates, where it is thicker and shallower.

The outer surface of the dentary is divided into an upper and lower tract in Swans and Geese by a groove which, beginning near the trace of the suture with the angular and surangular elements, curves feebly downwards as it advances forward: *Cygnus Ruppelii*, in this character, nearly repeats that in *Odontopteryx*.

The upper beak-bone in *Anatidæ* does not show the longitudinal groove which impresses it in *Odontopteryx*. But this groove is present in *Sula* and *Phalacrocorax*. It commences behind, in these sea-birds, a little in advance of the outer end of the naso-frontal suture, and extends straight forward, about midway between the upper and lower borders of the upper beak, to near its pointed termination. The groove (Pl. XVI. figs. 1 & 2, *g*) has the same relative position on the sides of the upper beak in *Odontopteryx*; but it begins below the fore part of the zygoma, and rises with a curve convex upward, to midway between the upper and lower borders of the maxilla, along which it then runs straight as far as that bone is preserved.

The upper part of the upper beak in *Sula* is broad and arched at its base, the transverse convexity being more marked as the beak narrows and advances. In *Odontopteryx* an upper tract is pinched off, so to speak, from the sides, flattened above at first, and becoming transversely convex as it narrows and advances, the sides of the beak below this tract being transversely concave in a feeble degree before attaining the groove (*g*). This upper median raised tract recalls the more strongly developed one in *Procellaria*, and suggests the possibility of its having been prolonged, in *Odontopteryx*, to terminate forward, as in Petrels, in the outer opening of the tubular nostrils; but the mutilation of the beak in the fossil leaves this point purely conjectural; and in all other comparable characters of the skull the resemblances are found with the Lamellirostrals and Totipalmates, not with the Longipennate sea-birds.

Another character approximates the fossil to *Sula*; there is no trace of a mid notch at the fore part of the frontal, into which, in *Anser palustris*, the end of the nasal branch of the premaxillary is produced; the transverse fronto-nasal suture abruptly defines the cranium from the beak in *Odontopteryx*, as in the Totipalmates. But the transverse contraction of the interorbital part of the frontal is more considerable in the fossil, and the hind part of the naso-premaxillary tract is flatter, with other differences from the Gannets and Cormorants already noticed.

Thus *Odontopteryx*, independently of its teeth, shows, in the unique fossil representing the genus, its distinctness from all known existing genera of birds.

Of the species which have the bill armed with tooth-like processes, the enumeration is easy. The true Falcons have the single "tooth" on each side of the upper jaw; a like armature of the beak of the Butcher birds has suggested the term "dentirostres" for the tribe of Passerines including the *Laniidæ*. The male of one genus

of Humming-bird has the same character, whence the name "*Androdon*." The Dodlet (*Didunculus*), of the Samoan Isles, has been called the "tooth-billed Pigeon," because of the notches leaving three pointed horny processes in the sheath of the lower bill, beneath and just behind the hook-like production at the end of the upper one. The alveolar borders of the bill in *Anatidæ* and *Phœnicopteridæ* are notched by transversely set laminæ: and these are produced and pointed in their fish-catching allies, the Goosanders and Mergansers.

But in all these cases the "teeth" of the ornithologist or "tooth-like processes" are horny, are confined to the sheath of the bill, and *there are no corresponding productions of the supporting bone*, the alveolar borders of which are even, or but minutely indicative of the horny teeth. It is true, as Geoffroy St.-Hilaire first pointed out, the beginnings of the horny sheath are due in some birds (Parrots, *e.g.*) to detached papillæ occupying shallow cavities of the borders simulating sockets; but the primitive tubercles run into each other, and are ultimately confluent with the beak-sheath*.

Perhaps a nearer approach to a dental structure is made where the hardening salts are in such excess as to give the sheath the character of ivory, welded to the bone, as in some Woodpeckers.

The production of the alveolar border into bony tooth-like processes is peculiar, according to my present observation of birds, to *Odontopteryx*. The closest repetition of this structure which I have yet seen is in the Australian Hooded Lizard (*Chlamydosaurus*); but the teeth are small, save the two at the fore part of each upper jaw and the single one at the same part of each mandibular ramus. The smaller teeth are so closely confluent with the alveolar border of both jaws as to seem to be processes: the larger anteriorly terminal teeth, though anchylosed to the bone, have their base defined by a ridge, suggesting the outlet of a socket, which is best marked in the lower jaw. All these teeth are tipped or capped with hard dentine; but such is not the case with the bony tooth-like processes in *Odontopteryx*. These seem, moreover, to have been sheathed with horn, or to have supported tooth-like processes of the horny beak; and their outer surface shows, though more feebly marked, the linear and punctate indentations relating to the vascular attachment of the horny to the bony beak. There is no trace of alveoli, although the cavity in the base of what seems to be a broken-off tooth at the fore part of the right upper jaw might be mistaken for one. I have not been able to detect, by application of lenses of any available power to the teeth *in situ*, any indication of a dentinal cap or apex.

After having myself outlined the drawings (which were finished as in figs. 1–6, Pl. XVI., with the care and accuracy characteristic of the accomplished artist, Mr. Griesbach) I had a mould and cast taken of the unique fossil to represent its original condition, and then selected the dental process which seemed best to promise evidence of tooth-structure.

Of this tooth (Pl. XVI. figs. 1 & 5, *e*) a longitudinal slice was taken (as in Pl. XVII. fig. 1) and laid, with some loss of the apex, upon a

* Anat. of Vertebrates, ii. p. 145.

glass slide. It showed large vacuities, especially at the attached base, filled with pyritic matter; and in the body of the tooth this matter occupied and demonstrated part of the vascular canals. These show chiefly a longitudinal course (Pl. XVII. fig. 1, *a*), or in the direction of the tooth's axis, united by short cross branches of minor diameter (*b*), including oblong spaces (*c*). The general arrangement being thus reticulate as in bone, the vascular substance not having filled a basal conical cavity, like the dentinal pulp of a true tooth, a large proportion of the osseous tissue of the process was preserved, showing, under a magnifying power of 250 diameters (fig. 2), the bone-cells. These have the proportions of length and breadth characteristic of the bones of birds, and also of Pterodactyles. Many of the bone-cells were in the direction of the long axis of the process, as at *a*, *a* (fig. 2), and averaged in length $\frac{1}{800}$ of an inch; others, nearer the vascular canals, were arranged in a direction at right angles to the long axis of the process, as at *b*, *b*, *ib.*: these indicated a short or transverse diameter of the cell of $\frac{1}{3000}$ of an inch. The canaliculi from the bone-cells were obliterated. Thus the microscopic test, in the degree in which I have been enabled to apply it, shows the osseous characters of the tooth-like processes, and adds to the probability of the conclusion drawn from the external vascular markings, that they were sheathed by hollow processes of the horny beak in the living bird.

With the exception of the better-preserved canaliculi in the microscopic sections of the bone-tissue of a fossil femur of a bird from Sheppey, figured by Quekett *, the size and shape of the bone-cells are much alike in that and the present fossil from the same formation and locality.

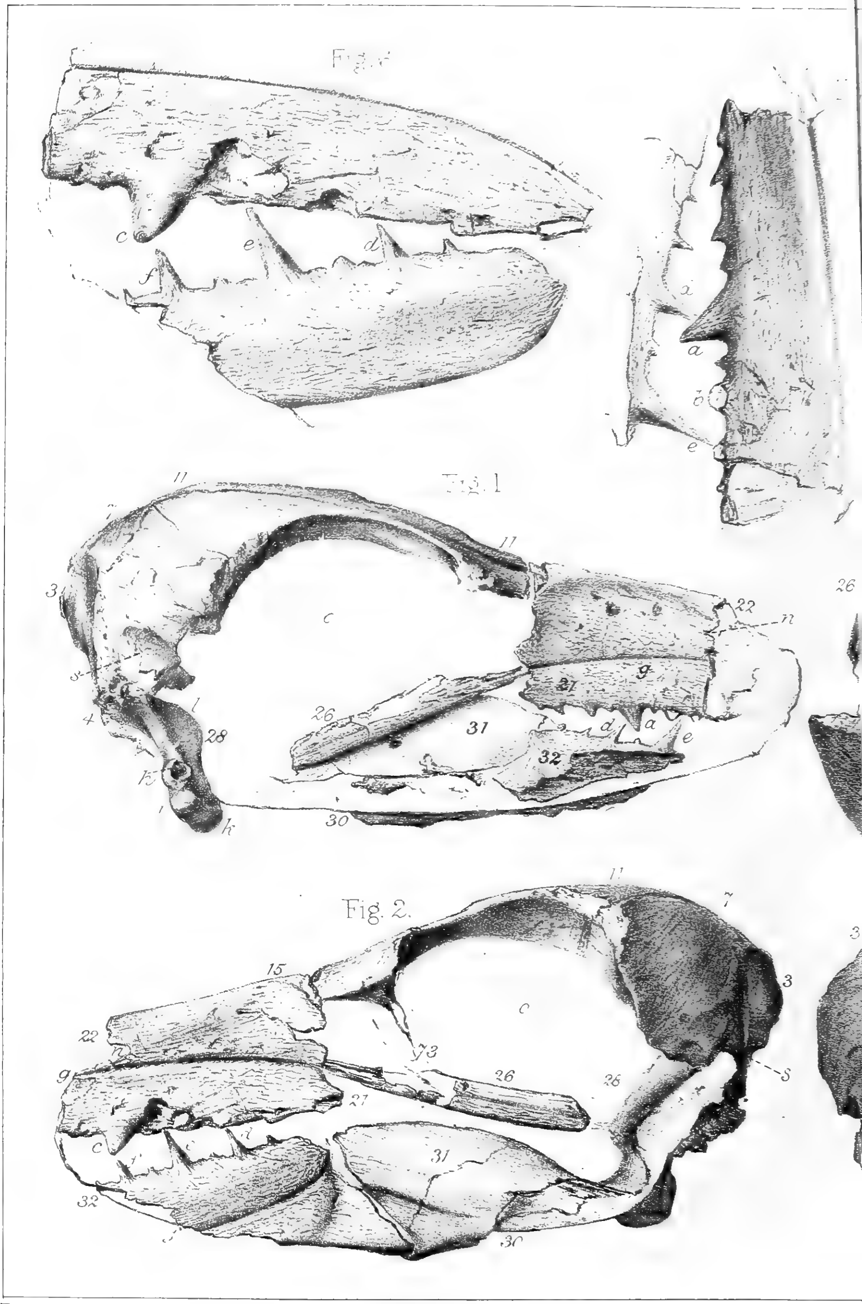
I conclude therefore that *Odontopteryx*, like *Archæopteryx*, was a warm-blooded feathered biped, with wings, and, further, that it was web-footed and a fish-eater, and that in the catching of its slippery prey it was assisted by this pterosauroid armature of its jaws.

The cretaceous fossil skull, affirmed by Professor O. C. Marsh to be that of a bird with teeth, and which he proposes as the type of a genus under the name *Ichthyornis*, also of an order which he calls "*Ichthyornithes*," and of a new subclass of birds under the name "ODONTORNITHES" or "*Aves dentatæ*" †, differs from the Sheppey fossil in having "the eyes placed well forwards," in having "the lower jaw long and slender," in having "the teeth quite numerous and implanted in distinct sockets," and in the size and shape of such teeth. They are described as being "small, compressed, and pointed, and all alike," or "similar." "Those in the lower jaw number about twenty in each ramus, and are all more or less inclined backward." "The maxillary teeth appear to have been equally numerous and essentially the same as those of the mandible" ‡.

* 'Histological Catalogue,' Museum of the Royal College of Surgeons, &c. 4to, vol. ii. plate x. figs. 34, 36.

† American Journal of Science and Arts, vol. v. 8vo, February 1873.

‡ *Id. ib.*



R. O. Del

ODONTOPTERY

Fig. 7

Fig. 8.

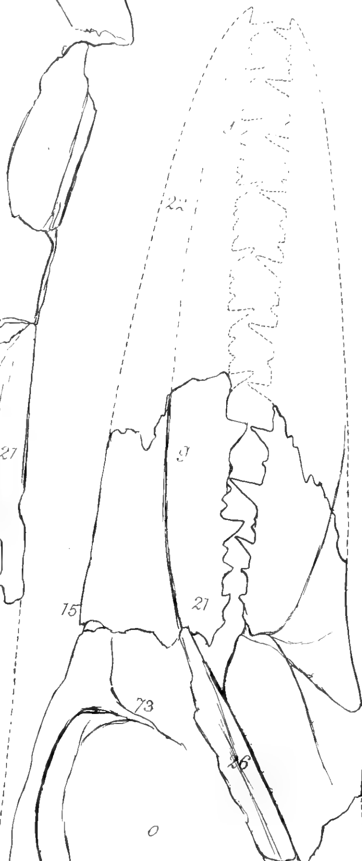
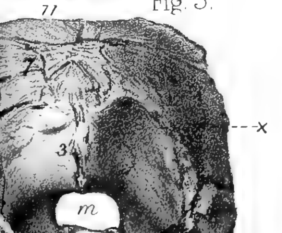
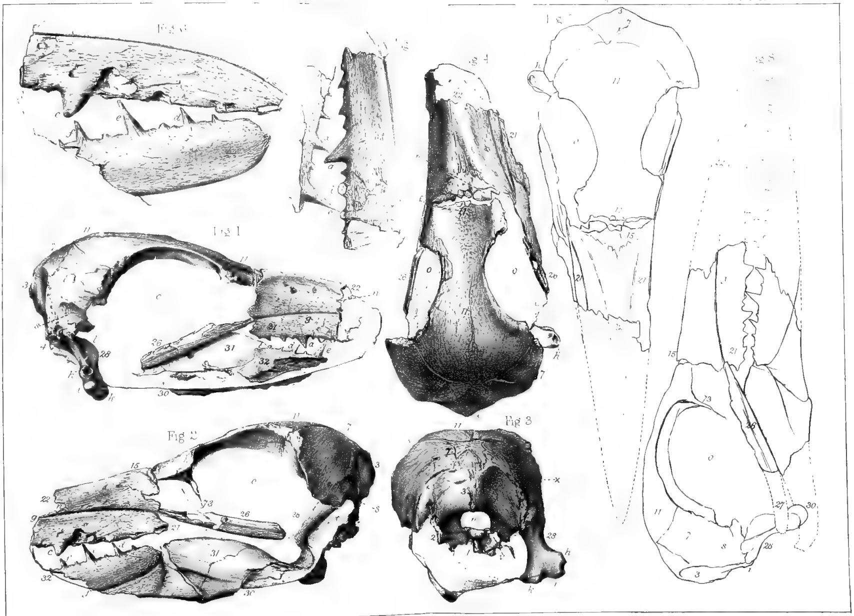


Fig. 4.

Fig. 3.



TOLIAPICUS.



R O Del

ODONTOPTERYX TOLIAPICUS

Fig. 1

Fig. 2.

D. Blair. del. | Hanhart. imp. | C. Griesbach. lith.

ODONTOPTERYX TOLIAPICUS.

Mandibular Tooth

When we are favoured with the description and figures of the *Odontornithes* by their accomplished discoverer we shall possess grounds for judging of the ordinal and higher relations of affinity between the Eocene toothed bird and the Cretaceous *Ichthyornis*. But the indications already vouchsafed by that active and indefatigable palæontologist suffice for an opinion of their specific and generic distinctness.

*Odontopteryx** has the orbits well within the limits of the hinder half of the skull; the lower jaw, though no doubt "long," has the rami too deep to bear the term "slender;" the teeth are separated by spaces which would not permit of their being reckoned as "quite numerous;" they are not implanted in sockets, but are represented by alveolar processes of the bone. It is true that some of them are "small," and all are "compressed and pointed;" but they are not "all similar" in respect of size: one, two, or three small teeth are interposed to the single, widely separated, large laniaries; finally, all the preserved teeth of *Odontopteryx* incline more or less forward instead of "backward."

EXPLANATION OF PLATES XVI. & XVII.

Plate XVI.

Fig. 1. Right-side view of the preserved part of the skull of *Odontopteryx toliapicus*, Ow.
2. Left-side view of do. do.
3. Hind or occipital surface, with right tympanic bone: *v*, portion of atlas.
4. Upper view of the preserved part of the skull of *Odontopteryx toliapicus*, Ow.

The above figures are of the natural size.

5. Preserved dentigerous parts of right side of both jaws; twice the natural size.
6. Preserved dentigerous parts of left side of both jaws; twice the natural size.
7. Outline of entire skull, conjecturally restored, from above.
8. Outline of entire skull, conjecturally restored, from the right side.

Plate XVII.

Fig. 1. View of a longitudinal section of the denticle, magnified 35 diameters and reduced one half.
2. View of a portion of the same section, magnified 250 diameters and reduced one half.

Discussion.

Mr. Seeley had given much study to the Pterosaurians, to which the author had indicated the affinities of *Odontopteryx*. He had in *Ornithocheirus Oweni* found what appeared to be identical structure with that of the bird; and it therefore appeared to form a new genus of Pterosaurians. Both in the frontal and occipital regions of the skull he recognized affinities to *Ornithocheirus*; but it presented even more distinctly marked reptilian affinities. The position of the brain was also quite as far back in the skull; and the quadrate bone also presented curious analogies, so much so as to be almost identical.

* I should have preferred the term *Odontornis* for my genus; but it is bespoke for Marsh's subclass.

The sutures presented characters similar to those exhibited by immature birds; and he thought that the separation of the bones in this example showed affinities to the anserine type. He was quite prepared to regard the fossil as that of a bird rather than of an Ornithosaurian. He inquired as to the character of the palatal bones.

Mr. Charlesworth inquired as to the light in which this discovery would be regarded by evolutionists.

Prof. Owen briefly replied.

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3. Contribution *to the* Anatomy *of* Hypsilophodon Foxii. *An* Account *of some recently acquired* Remains. By J. W. Hulke, Esq., F.R.S., F.G.S.

[Plate XVIII.]

In 1849 a block of sandstone containing a considerable portion of a reptilian skeleton was found by some labourers on the south-west shore of the Isle of Wight, near Cowleaze Chine. It was broken in two; and one piece passed into the collection of the late Dr. G. Mantell, the other into that of Mr. Bowerbank. Subsequently both pieces were acquired by the British Museum and reunited. Thus completed, the slab exhibits a continuous chain of some 18 presacral vertebræ, succeeded by the right ilium, the middle of which is crushed and hidden by an imperfect metatarsus. Below this are some long slender bones, which have received different interpretations from distinguished anatomists; and behind these are the left femur and a series of 12 caudal vertebræ. In 1855 a description of this fossil, illustrated by a plate, was given by Professor Owen, in his 'Fossil Reptiles of the Wealden Formations' (vol. 1855, Older Dinosauria, p. 2), where it is entitled "Part of the Skeleton of a young Iguanodon, *I. Mantelli*,"—a conclusion towards which the weight of evidence then seemed to incline. In 1867 Prof. Huxley, from a comparison of its vertebræ with those of *Iguanodon*, and from the presence of four metatarsals in the pes, concluded its generic distinctness from *Iguanodon Mantelli*; and in 1870 he made it the subject of a communication to this Society. Prof. Huxley prefaced this paper by a detailed description of a small reptilian skull discovered by the Rev. W. Fox in the same stratum from which the Mantell-Bowerbank fossil had been obtained. It had been previously exhibited by Mr. F. Fellows for Mr. Fox, at the Norwich Meeting of the British Association, 1868, when Mr. Huxley drew attention to the remarkable facts that the teeth contained in the posterior moiety of the præmaxilla were quite different in shape from the maxillary teeth, and that the anterior moiety of the præmaxilla was beak-like and edentulous. The maxillary teeth, though presenting a general resemblance to those of *Iguanodon*, at the same stage of wear, yet appeared, on close examination, so distinct as not to leave any doubt of the generic distinctness of this reptile; and Mr. Huxley proposed for it the generic name *Hypsilophodon*, and called the species *H. Foxii*, after its fortunate discoverer. The preservation of a vertebral

centrum in the same block of stone with the skull further enabled Mr. Huxley to identify *Hypsilophodon* with the Mantell-Bowerbank skeleton.

In the discussion which followed the reading of this paper I alluded to part of a reptilian skeleton from the same cleavage-bed, shown me by Mr. Fox in 1869, which I considered to belong to *Hypsilophodon*. It consisted of a connected chain of several pre- and postsacral vertebræ, the right ilium with the proximal end of the femur in the acetabulum, and the distal half of the leg with the tarso-metatarsus. The ilium was prolonged forward for a considerable distance in front of the acetabulum. The knee-joint had been worn away; but its position in the block, ascertained by prolonging the directions of the remaining parts of the tibia and femur, made it very probable that the leg was longer than the thigh.

The above are all the published notices of the anatomy of *Hypsilophodon Foxii* with which I am acquainted.

In several visits to the Isle of Wight I have obtained additional evidence of its structure; and having quite recently been so fortunate as to exhume from the same Cowleaze bed great part of a skeleton of this reptile, I am now able to communicate many details respecting its dentition, and also the form of the mandibular symphysis, not illustrated by Mr. Fox's skull, as well as the forms and proportions of several bones of the shoulder and hip-girdles, and fore and hind limbs, before unknown.

Probably the entire skeleton was present; but its immaturity and the fissured state of the clay in which it was lying were so unfavourable to the preservation of the bones, that most of them were too much shattered to bear removal, and of many I could only bring away ideas, the bones themselves falling into numberless small pieces, which no pains or ingenuity could join.

Skull.—The only remnants of this which I could save were parts of the jaws and of one orbit. In the clay filling the orbit were several small osseous scales, which I judged to be vestiges of a sclerotic ring; and deeper than these was a large and extremely thin bony lamina, apparently an extensively, if not, indeed, completely, ossified interorbital septum.

The largest piece of jaw is the right mandibular ramus (Pl. XVIII. fig. 1). The outer surface and dentary border are laid bare. Its length from the front of the symphysis to the front of the quadratic joint (behind which the bone is defective) is 2·5 inches. The upper border slants from the quadratic joint steeply upwards to the coronoid process, the top of which is wanting; and from here it declines gently forwards through a space of 1·6 inch, which comprises the entire tooth-bearing portion. In front of this, at the distance of ·35 inch from the symphysis, it abruptly falls; and the surfaces, which behind this point look inwards and outwards, acquiring an upward and downward aspect, one half of an edentulous mental interdentary groove (fig. 1, *a*) repeats in miniature the characteristic depressed symphysis of *Iguanodon*. In front of this extremity of the mandible, and quite distinct from it, is a thin triangular plate, which I suspect

to be the edentulous beak-like part of the præmaxilla, known to us by Mr. Fox's skull. That which I judge to be the trenchant border has the same length as the edentulous part of the mandible.

Teeth.—The other remnants of upper and lower jaw, though very fragmentary, throw new light on the dentition of *Hypsilophodon*, so that, with this and several teeth which had fallen out and were recovered from the clay by washing, I can now illustrate nearly every phase in the life of a tooth, from the immature crown, which had not come into use, to the worn-out stump.

The right mandible just described had at least ten mature teeth in use, of which the crowns of four only remain; and these exhibit the characters of the maxillary teeth of Mr. Fox's skull. The last tooth is smaller than those immediately before it. The 2nd–6th, counted from behind forwards, were larger than the four next preceding them. The crowns of three of these are broken off and lost; but one remains. It is worn nearly to the root; and a young unused crown rising up at the inner side of this stump shows these teeth to have corresponded in shape and size to the anterior smaller maxillary teeth in Mr. Fox's skull. Between the foremost of these teeth and the edentulous extremity of the jaw, the outer parapet of the dentary bone has been broken away: no teeth remain here; but I fancy I can discern traces of three alveoli suitable for the reception of the roots of teeth of the cylindrical form, such as are present in the hinder part of the præmaxilla. In the clay, at a short distance, lies one such tooth; and near this is the impression of another. As in Mr. Fox's skull, so here, there are two forms of tooth—one simple and cylindrical, the other ornate and strongly compressed.

Cylindrical teeth (fig. 7).—A perfect, mature tooth of this sort measured ·4 inch; of this, nearly ·15 belong to the crown, which is separated from the root by a slight constriction or neck. The root is slightly contracted towards each end, and dilated in the middle; its cross section is nearly circular, and its surface is smooth. Two, which I slit longitudinally, had a very large pulp-cavity filled with spar. The crown is slightly and unequally compressed, the inner contour of its cross section being slightly more convex than the outer. Its apex is acuminate, and is slightly inflected, which renders the outer longitudinal outline convex, and makes the inner one sinuous, concave near the point, and convex towards the root. The outer and inner surfaces meet angularly, making a low wing, within which and parallel with it, upon the inner surface, is a minute shallow longitudinal groove. In very perfect unworn crowns, the marginal wing bears a row of minute tubercles, just visible in a strong light to the unaided eye. Both surfaces are highly polished and smooth; upon the outer a few very minute longitudinal striæ are discernible. Towards the neck the surfaces are beset with excessively minute tubercles (not recognizable as such without a magnifier), the collective effect of which to the unaided eye is an extremely fine wrinkling.

Compressed sculptured Teeth (figs. 4, 5, 6).—Both the varieties described by Prof. Huxley from Mr. Fox's skull are amply illustrated by my specimens, the smaller variety occurring in the front of the maxil-

lary series, and the larger form occupying a posterior position. In both varieties one surface of the tooth (that towards the cavity of the mouth in the lower jaw, and the outer in the upper jaw) is exquisitely sculptured by longitudinal ridges passing from a raised cingulum at the junction of crown and root to the free border of the crown. The general outline of the crown is subrhomboidal. Both surfaces, longitudinally and transversely, are convex. In a nearly perfect tooth of the smaller variety (fig. 4), which had only just come into use, the cingulum forms an angle open towards the summit of the crown. The principal ridge runs from the open nearly axial angle to the trenchant border, and it forms the apex of the crown. At each side of it is a small secondary ridge; one of these does not quite reach the cingulum. Between the free ends of these minor ridges, which give this part of the border of the crown a coarse serration, and the lateral terminations of the cingulum, the sides of the crown are very finely serrated, recalling in miniature the marginal serrature of the teeth of *Iguanodon Mantelli*. In the larger variety the ornamented surface of the crown is sculptured by a greater number of ridges; and these are more equal in size (fig. 6). Some of them divide near the trenchant border of the crown, rendering this, when unworn, beautifully crenated; and the sides of these larger teeth are beautifully serrated, as in the smaller variety. The cutting-border of these larger teeth, before it has been worn, is rounder in outline and less angular than that of the smaller ones. The unridged surfaces of the crowns bear a few very minute inconspicuous striæ. All crowns which have risen above the crest of the outer parapet of the jaw bear marks of wear. They are obliquely ground; the sculptured surface remains longest, and it forms a cutting-edge, which is at first serrated by the cross sections of the longitudinal ridges, but later becomes merely sinuous as these grow less prominent in the level of the lateral angles of the crown. The maxillary tooth of Mr. Fox's skull, figured in pl. 1. vol. xxvi. Quart. Journ. Geol. Soc., is thus worn. The worn surface of large crowns is marked by slight elevations not deserving the name of ridges, running between the inner and outer surface; and the attritional striæ, which are discernible in all worn teeth, have the same direction. By the time that the crown has become worn down to the level of the outer border of the jaw, the long cylindroid fang also has nearly disappeared, so that very slight force would detach the remnant of a tooth in this condition. The successional teeth rise at the inner side of the old ones, as in existing lizards.

Attachment of Teeth.—A transverse section through the fang of a cylindric tooth *in situ* shows it to be contained in a distinct, separate socket. With respect to the compressed teeth, I am inclined to think that the same does not strictly obtain. As in *Iguanodon Mantelli*, the outer wall of the tooth-groove sends inwards partitions, which practically separate the teeth from one another, and must have afforded them a very firm support; but I doubt if these partitions actually reached the inner wall and became confluent with it.

The general form and the facies of the cylindrical teeth of *Hypsilophodon* are so like those hitherto generally regarded as Hylæosaurian that I cannot help suspecting that these reputed Hylæosaurian teeth may really be the as yet unknown premaxillaries of Mantell's *Iguanodon*; and the suspicion derives strength from the fact that these teeth are not very rare in those Isle-of-Wight Wealden beds which also yield *Iguanodon* remains, whilst other indisputable remains of Hylæosaurians are extremely infrequent anywhere in the island Wealden formation.

Vertebral Column.—All the vertebræ were crushed and mutilated beyond reparation. A few centra which I recovered show that both articular surfaces are nearly plane; or else the periphery is plane or gently swollen, and the middle is very slightly hollowed. The outer or non-articular surface is smooth. The sides are scarcely convex vertically, and slightly concave horizontally. In all the vertebræ the neurapophysial suture persists, as Prof. Owen found in the Mantell-Bowerbank skeleton; and the neurapophysis had, in most instances, separated from the centrum. The neural canal, in the neck-vertebræ, is very capacious; and the spinous processes are dwarfed here. The neural surface of the centrum has a narrow longitudinal median groove not covered by the neurapophyses, a fact mentioned by Prof. Owen. In some centra this groove has the form of a deep cleft, which sinks below the level of the middle of the centrum.

Two centra from, I think, a little in advance of the sacrum are respectively ·7 and ·65 inch long, and ·4 inch in their vertical diameter. A mutilated sacrum of an older individual consisted of four anchylosed centra, with a small remnant of a fifth.

Ribs.—Associated with the vertebral column of the base of the neck and front of the chest were many fragments of double-headed ribs.

Shoulder-girdle and fore limb.—The scapula, coracoid, and left humerus I found lying close together; and near these, in other blocks of clay (for the cliff was very fissured), was a forearm with its manus, and a flat bone, presumably the sternum.

The scapula (fig. 2, *a*) is a long thin slightly recurved blade, a little expanded at the vertebral end, and widening considerably towards its articular extremity. Its anterior margin, in the middle two thirds, is nearly straight; towards the ventral end it bends forwards and includes an acute angle with the coracoid border, whilst dorsally it curves backwards. The expansion of its dorsal and ventral ends renders the posterior border concave. The articular border is divided into two facets, of which one is longer, straight, anterior, for union with the coracoid; and the other, shorter, stouter, and posterior, forms half of the glenoid fossa (fig. 2, *b*). These two facets, in my specimen, include an angle of about 125°. A larger scapula, of a probably mature individual, had a longer and narrower blade, and what seemed to me a short precoracoid process.

Compared with the scapulæ of other Dinosauria, that of *Hypsilophodon* (particularly when fully grown) resembles that of *Iguanodon Mantelli* in the length and narrowness of the blade, and, unless appearances have misled me, in the presence of the precoracoid pro-

cess; from that of *Scelidosaurus Harrisoni* it differs in the smaller expansion of its dorsal end; and from that of *Hylæosaurus* in the absence of the stout acromial ridge which marks the bladebone of this reptile; whilst to the stupendous scapula of *Ceteosaurus oxoniensis* my immature bone has a general likeness.

The *Coracoid* (fig. 2, *c*) is a thin, flat, subsemicircular bone. It touches the scapula, but it has slipped a little backwards from it. Its scapular border is straight. The glenoid border is the stoutest part of the bone. Between it and the longer straight scapular border is a small notch, and between the posterior glenoid lip and the sternal margin is a large deep incurve. The sternal margin is thin, and its outline is an arc. In an older individual, the bones of which were harder and the matrix better adapted to preserve them, this arc in curve and in length agreed with the corresponding border of an adjacent sternum. The coracoid of this individual was also pierced by a foramen near the union of the glenoid and scapular borders, of which only a trace is discernible in my squeezed immature bone.

Sternum.—A thin shield-like bone, pressed quite flat, lying close to the coracoid, was probably the sternum. It broke to bits with the block of clay in which it was imbedded, during my efforts to extract it from the cliff. The same bone, or rather its anterior moiety, in another individual, here also associated with the coracoid, had a semirhomboidal form. The front or intercoracoid angle was truncated and emarginate; I roughly judged its length to nearly equal one third of the width of the coracoid, measured between the sternal and glenoid borders. The coracoid margin of this sternum agreed in the form and extent of the curve with that of a near-lying coracoid. Mesially, the lateral halves of this sternum included a large angle, the ventral surface of which was smooth and keelless.

Humerus (fig. 2, *d*).—The left arm-bone lies parallel with the front border of the bladebone, and partly hidden by it. Its length, 3·4 inches nearly, equals that of the bladebone. The proximal end bears a subhemispherical articular head (*e*), placed nearly in the middle, and prolonged upon the dorsal or anconal aspect of the bone. A large crest marks the radial border of the shaft near the proximal end. The shaft itself is somewhat twisted. The ventral surface of the distal end is hidden.

Forearm.—The greatest part of both bones of the forearm could not be preserved. The ulna, for its size, has, I think, as large an olecranon as that represented in Prof. Owen's plate of this bone in *Iguanodon*, issued by the Palæontographical Society last year. The radius is much broader at the wrist than the ulna, and it forms the principal support of the manus. The radius of a mature individual I found to be 4·87 inches long, the ulna slightly more; and the humerus was 5·75 inches in length.

Manus (fig. 3).—The bones of the fore foot, together with the distal ends of the radius and ulna much crushed, were lying disconnected and confusedly in the clay, near the larger mass containing the shoulder-blade and coracoid. Two carpals are discernible, one of

which may be a lunare, and the other, from the coaptation of one of its articular surfaces, may be the corresponding ossicle in the second row. Two metacarpals and the proximal end of a third are recognizable. Their lengths are ·67 and ·7 inch. The proximal ends are squared and stout, the diaphysis is slender, and the distal end pulley-shaped. Seven digital phalanges remain, of which three are ungual. Of the four others, the two larger are respectively ·3 and ·25 inch long, which is nearly twice their transverse diameter taken midway between the articular ends. The two smaller phalanges are ·5 and ·2 inch long; and even these, relatively to their width, are longer than corresponding phalanges in the manus of Mantell's *Iguanodon*. The unguals (*a*, *b*) are nearly straight, sharply pointed, and they are not depressed and flattened as those of *Iguanodon*, from which they also differ in the presence of a conspicuous claw-groove, which runs inside the upper surface of a slightly projecting border that separates the upper from the under surface of the phalanx.

Haunch and hind limb.—I did not recover the ilium; but three from two other individuals were strikingly like those displayed in the familiar *Iguanodon*-slab from Maidstone, preserved in the palæontological gallery of the British Museum. The upper border, which is rather stouter than the broad plate below it, is prolonged forwards above and beyond the acetabulum as a long, slender process, which I have not seen complete, but which, in a nearly perfect specimen, was about as long as the postacetabular part of the bone. In these three examples the lower preacetabular, or pubic process, was well marked. It was directed downwards and forwards when the axis of the ilium was placed parallel with that of the vertebral column. The ischial articular facet was a slightly swollen eminence, not deserving, any more than in Mantell's *Iguanodon*, to be called a process. Behind the acetabulum the lower border of the bone is directed almost horizontally backwards, and it makes a blunt angle with the upper border, which bends downwards and meets it. The postacetabular part of the broad plate, or body of the ilium, at the level of about two thirds of its depth from the upper border, is angularly inflected towards the mesial line beneath the sacrum. The inner surface is stamped, as in *Iguanodon*, with a sinuous impression of alternating elevations and depressions corresponding to the shape of the outer surface of the confluent sacral transverse processes. The pubes and ischia are known to me only in the Mantell-Bowerbank skeleton.

Femur.—The thigh-bone has a general resemblance to that of *Iguanodon*; but it may easily be distinguished from this by the form, relative size, and the position of its inner trochanter. This, when perfect, is a large triangular wing pointing downwards, and situated nearer the proximal end of the thigh-bone than in Mantell's Dinosaur. The head is subglobular, and it is borne on a distinct neck, which makes almost a right angle with the axis of the shaft. In two very perfect and undistorted examples, the proximal end of the shaft was laterally compressed in such a way that its surfaces looked outwards and inwards when the neck was supposed to be directed ver-

tically to the plane of the ilium. A thin, slender, outer trochanter, separated from the upper end of the shaft by a narrow fissure, strongly recalls the similar process in the thigh-bone of *Iguanodon*. The shaft has an outward twist, larger, I think, than in *Iguanodon*. The femoral condyles are strongly developed, and they project very strongly backwards, separated here by a very deep intercondyloid groove. The anterior intercondyloid groove is worn away in the Mantell-Bowerbank femur, and it is effaced by squeezing in my specimen; but I have seen it a well-marked deep groove, differing, however, from the groove in the femur of *Iguanodon* by the absence of overhang, the lips of the groove in *Hypsilophodon* not being inclined towards each other, and not forming the tunnel which marks the thigh-bone of the great Dinosaur. The length of my femur cannot now be ascertained; but those of three others were 7, 7, and 5·12 inches.

Tibia (fig. 8, *a*).—I have secured in one block the distal end of the tibia with the pes. The length of this shin-bone cannot be learned; but that of a beautifully perfect example from another individual was 9·25 inches, the femur of the same being 7 inches long. The proximal end of this bone was divided into two condyles, answering to those of the femur, but not so strongly marked as these were; and beyond the outer condyle a large crest projected forwards and outwards from the front of the upper part of the shaft. The axis of the shaft has a strong twist in the same direction as that of the femur. The distal end is transversely expanded, and it closely repeats that of the *Iguanodon*.

The fibula is very imperfectly known to me; I believe it to be rather shorter than the tibia.

Pes (fig. 8).—The astragalus is disconnected from the tibia in my specimen; but in two other examples I have seen it attached to it. Its lower surface is pulley-shaped, convex from back to front, and sinuous transversely, being in this direction convex laterally and hollow mesially. The upper surface is concave from back to front, and in this direction it is subdivided by a ridge which marks off two facets answering to those on the distal articular surface of the tibia. The anterior margin is a very thin lip: in my specimen the extreme edge has been broken off; but its thinness is such that it cannot have here been produced into a bird-like ascending process. The posterior border is stouter.

Under the distal end of the tibia, and partially hidden by it, are two small bones, probably tarsals; the larger and outer one may be a calcaneum.

There were certainly four (if not five) toes, of which the outer three are well preserved; their ossicles still maintain, with only slight disturbance, their proper relations. The metatarsals are long and stout; their proximal ends have been flattened by a hard sandstone nodule. The middle one (the longest) measures 2·8 inches long; the outer one is 2·3 inches, and that on the inner side of the central one is 2·5 inches long. Displaced, and lying beneath these three, athwart them, I discovered an ungual phalanx, and not far

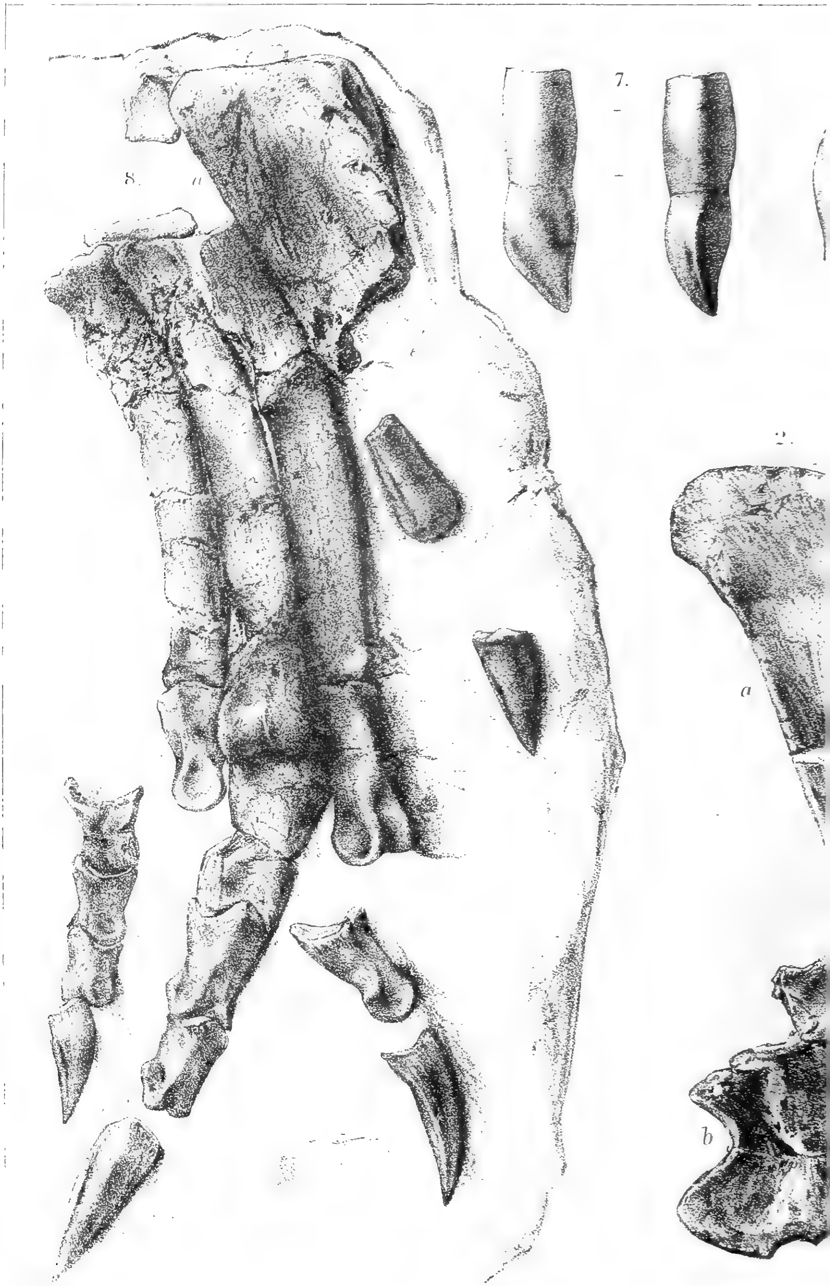
from it a fourth and smaller metatarsal. I have extricated them from the matrix, and placed them at the inner side of the pes, as the form of the metararsal plainly indicates it to have had this position. The three toes following this inner one, counted from the tibial to the fibular border of the foot, have respectively 3, 4, 5 phalanges. They answer therefore to the 2nd, 3rd, and 4th toes in the foot of existing lizards; and I assume the small displaced toe to be the 5th; in which case it wants the basal phalanx. The other basals and the intermediate phalanges are stout, moderately long, and their distal, pulley-shaped, articular surfaces are strongly marked. The unguals are large, long, straight, and sharply pointed. They have a very conspicuous marginal claw-groove. The third is the stoutest toe; and although it has one phalanx less, it is longer than the 4th, the basal 2nd, 3rd, and 4th phalanges of which are shorter than any others, in which respect they somewhat resemble those of the corresponding toe of the *Iguanodon*.

Comparing *Hypsilophodon* with what is known of *Iguanodon* (for its anatomy has still many voids), the following seem to me to be some of the most striking resemblances and differences. *Hypsilophodon* resembles the larger Dinosaur in the peculiar form of the anterior extremity of its mandible, in the general facies of its compressed sculptured teeth (longitudinally ridged and marginally serrato-lamellated), in the form of the bones of the shoulder-girdle and also in that of the haunch-bone, in the greater size of the hind limb, the greater length and stoutness of the third toe (which corresponds in the number of the phalanges to the middle toe of *Iguanodon*). It differs from *Iguanodon* in having four toes *, in the absence of that extreme shortness which marks the phalanges, especially of the outer toe of *Iguanodon*, and in the form of the unguals, which are long, tapering, and pointed—in the tibia being longer than the femur, the reverse of which obtains in *Iguanodon*—in the inner femoral trochanter being nearer the proximal end of the thigh-bone, and in the want of overhang of the margins of the anterior intercondyloid groove which marks the thigh-bone of *Iguanodon* and of *Hadrosaurus*—and particularly, as regards the manus, in the straight, symmetrical, distinctly claw-grooved unguals, which are wholly unlike the shapeless depressed unguals of *Iguanodon*, devoid of distinct groove for attachment of claw.

Hypsilophodon resembles *Scelidosaurus Harrisonii* in the number of the pedal digits, and, superficially, in the facies of the compressed teeth. This last resemblance, however, is weakened by a critical examination of the specimens themselves. In both the crown is separated from the root by a cingulum, the sides of which run out on the lateral margins of the tooth; but in *Scelidosaurus* no ridges pass longitudinally from the cingulum to the trenchant edge of the crown †, and the serration has quite a different shape.

* *Iguanodon* has three functional toes only, the splint-like bone, thought to represent a first toe, not being segmented into phalanges.

† The artist has not been so successful as usual in the figure of a tooth which illustrates Prof. Owen's memoir on the skull of *Scelidosaurus* in the Foss. Rept.

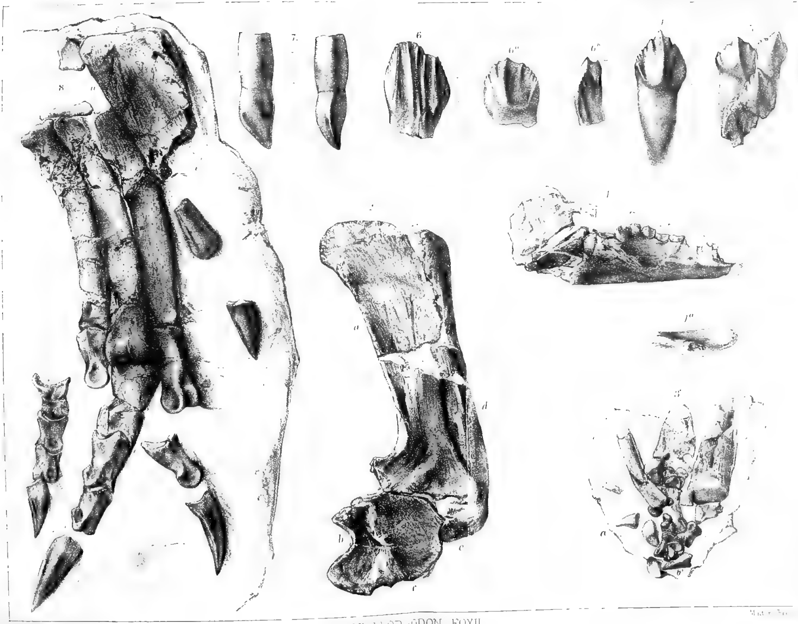


G.H Ford & C.L.Griesbach

HYPSILO

ODON FOXII.

Mintern Bros imp.



G.H. Ford & C.L. Griesbach

HYPSILOPHODON FOXII

Mintern Bros.

EXPLANATION OF PLATE XVIII.

All the figures, except those of the teeth, are of the natural size. The size of the teeth is indicated on the plate by lines.

Fig. 1. Outer surface of right ramus of mandible.
1 *a*. Its edentulous anterior extremity viewed obliquely from above.
2. *a*, scapula; *b*, its humeral articular surface; *c*, coracoid; *d*, humerus; *e*, its proximal articular head.
3. Manus. *a*, *b*, claw-bones.
4. A perfect tooth of the smaller compressed form.
5. Two worn teeth of this kind, upon which lies a young tooth.
6 and 6*a*. Two of the larger compressed teeth. 6*b*, a side view of 6*a*.
7. Two views of a cylindrical tooth.
8. The pes. *a*, distal extremity of the tibia.

Discussion.

Prof. Owen remarked that palæontologists generally were interested in obtaining such additional evidence of the generic characters of *Iguanodon* as Mr. Fox's valuable discovery of the skull and other remains of the small species in the Isle of Wight Wealden might supply; but such desirable information, especially as regards the cranial structure of the herbivorous Dinosaurs, is shut out if those remains are shown to belong to a distinct genus. In the paper to that end in the 'Quarterly Journal' for 1870, p. 3, the only teeth of the so-called *Hypsilophodon* known to the writer were those of the upper jaw, and these were not entire; the portion of crown answering to the serrated portion in *Iguanodon* was worn away. Mr. Fox was therefore justified in rejecting Prof. Huxley's genus *Hypsilophodon*, although he might believe the statement that such serrations were characteristic of the teeth of *Iguanodon*, especially when emphasized by the phrase "so characteristic"—the fact being, however, that marginal serrations characterize the apical half of the crown in the Dinosaurian genera *Scelidosaurus* and *Echinodon* as in *Iguanodon*. What are truly characteristic of the upper molars of that herbivorous Dinosaurian are the ridges on the outer surface of the crown, which ridges, being also present in Fox's *Iguanodon*, and supposed to be peculiar thereto, suggested to Prof. Huxley the term *Hypsilophodon*. But the lower molars of *Iguanodon* are equally ridged, but on the opposite side to those above, viz. the inner side; and the marginal serrations extend nearer to the base of the crown. Now the lower molars of the small *Iguanodon*, also found, with the mandible, by Mr. Fox, show this generic character, and vindicate the taxonomy of their discoverer. We may rest assured, therefore, that the sloping edentulous symphysial part of the mandible of the great *Iguanodon* had a downbent edentulous part of the premaxillaries applied to it, such as the fore part of the skull of *Iguanodon Foxii* exhibits. Without a knowledge of the

of the Lias. A stout median ridge is depicted going from the retiring angle of the cingulum to the apex of the crown, which I fail to find: to me it appears that a transverse section of the crown would have its outer contour a simple unbroken curve, having its maximum excursion at the middle line of the outer surface, but uninterrupted here by any angle or bend marking the cross cut of a ridge.

characters of both upper and lower molars of this small *Iguanodon*, no one in quest of the truth of the matter could affirm "that the teeth of this reptile were perfectly distinct from those of *Iguanodon Mantelli*." In the last plate of Prof. Owen's 'Monograph' for the forthcoming volume of the Palæontographical Society, the mandible and mandibular teeth are figured; and he had hoped to receive a proof to show to the Meeting. The mandibular teeth exhibited by Mr. Hulke were identical with those previously discovered by Mr. Fox. In the 'Monograph' the evidence will be found of the specific, but not generic, distinction of Mr. Fox's small Dinosaur from the large *Iguanodon Mantelli*.

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4. *On the* Glacial Phenomena *of the* Long Island *or* Outer Hebrides. By James Geikie, Esq., F.R.S.E., of H.M. Geological Survey of Scotland.

First Paper.

I. *Introduction.*

The detailed observations of the Geological Survey having led my colleagues and myself to conclude that the great *mer de glace* which enveloped the south of Scotland during the intensest cold of the Glacial Epoch was so extensive as entirely to fill up the basin of the Clyde, and all the sea between Ailsa Craig and the mainland, I became curious to ascertain what the islands of the Outer Hebrides had to tell us in regard to the extension of the old ice-sheet in that direction. My brother had in 1865 shown that the island of Bute was glaciated from end to end by the ice that streamed outwards from the mountain-glens of Argyllshire; and subsequent observations by myself in Ayrshire had proved that the rocky coasts between Lendalfoot and Glen App were striated in a direction parallel to the shore-line by glacier masses which flowed south-west upon what is now the bed of the sea. My colleague, Mr. D. R. Irvine, had also found that ice from the southern uplands had swept across the Rinns of Galloway from the interior of the country —the whole coast between Portpatrick and Corsill Point exhibiting numerous rock-striations and glaciated surfaces, whose prevailing direction is towards south-west. Thus it would appear that an immense mass of glacier ice, derived partly from the Highlands and partly from the Southern Uplands, set towards the north coast of Ireland. Moreover the position of the striæ and the whole character of the glaciation of that south-west part of Scotland induces the belief that the Scottish *mer de glace* became confluent with that of Ireland, splitting upon the northern coasts of Galway and flowing south into what is now the Irish Sea, and west into the Atlantic. But to what extent that ice-sheet stretched seaward, it would be premature at present to offer even a conjecture. That we shall yet be able to form some approximately true estimate of the depth and breadth of the *mer de glace* can hardly be doubted. Towards this end, it obviously becomes important to trace the direction of

glaciation upon those islands which are furthest removed from the mainland. If these shall be proved not to have been visited by extraneous land-ice, then we shall have a known limit to the breadth of the *mer de glace*. On the other hand, if it should be put beyond all doubt that even the remotest island has been overflowed by the general ice-cap that covered the mainland, then we shall have advanced so far towards forming such an estimate as I have hinted at. In a future paper, I hope to take up this particular point. The present communication is limited to a description of the older glacial phenomena of Lewis.

II. *Lewis—its physical features.*

Lewis, or the Lews, as it is frequently called, forms the northern portion of that long string of islands which, taken collectively, are generally styled "The Long Island." In the south it is broken and mountainous; but with this exception, nearly all the rest of the island is low-lying and gently undulating. Immediately south of Stornoway and along the northern shores of Loch Roag, the ground is broken and rocky; but north of a line drawn between the head of Loch Erisort and Gearaidh nah Aimhne, the whole of the island might be described as one great extended peat-moss, rising gradually from the coasts to an average height, at the watershed, of about 400 feet. In many places, however, the rock peers through the peat and heath; and the ground occasionally reaches an elevation several hundred feet higher. A few such elevations form conspicuous land-marks in the north of Lewis. The highest point, however, is not much more than 900 feet (Beinn Barabhais); but rising, as it does, somewhat abruptly out of an undulating peaty plain, it obtains an importance which it does not otherwise deserve. A rapidly waving line drawn from near the Butt, south-east through Beinn Barabhais to Beinn nan Surrag, marks the watershed of this dreary district.

From the Butt to Aird Laimisheadar the land opposes to the swell of the Atlantic a long straight line of bold cliffs nowhere penetrated by any considerable inlet; and the coast-line of the north-east side of the island, between Stornoway and the Butt, although more undulating, and running here and there into capes, presents much the same character. But south of Aird Laimisheadar in the west, and of Stornoway in the east, the land is ever and anon penetrated by long sea-lochs that stretch into the heart of the country, and in one place, at least, nearly succeed in cutting off a large segment from the island—the distance between the heads of Loch Seaforth and Loch Erisort being little more than one mile and a half.

The south and much smaller part of Lewis, adjoining Harris, differs completely from the north in being almost wholly mountainous. The change from the northern moorlands to this hilly tract is singularly abrupt. The mountains appear to rise quite suddenly out of comparatively flat and low-lying ground, and have thus, like the smaller hills in the north of the island, an imposing appearance, which is hardly

justified by their actual height; for only two points reach an elevation of 1800 feet. They exhibit for the most part a rounded and flowing outline, but in many places are broken and rugged, and show considerable slopes, the most abrupt perhaps being Suainabhal in the north-west.

The geologist is not long in Lewis without being struck with the enormous number of fresh-water lakes that almost everywhere diversify the face of the island. These are of all sizes, from mere ponds up to lakes two, three, and even six miles in length. Taken altogether they must occupy no inconsiderable portion of the surface of the island. One may count upwards of fifty in an area of only four square miles. They are most abundantly developed upon the low, undulating, and sometimes rocky ground that extends from shore to shore along the base of the southern mountain-tract. North of a line drawn from Loch Carloway to Stornoway, they become less numerous, although they are still sufficiently plentiful to form a striking feature in the scenery. In the southern mountain-tract there is hardly a valley that does not contain one or more.

III. *Geological structure of Lewis.*

The greater portion of Lewis, as Macculloch long ago pointed out, consists of gneiss and its varieties. The only other rocks met with in the island are granite (at Delbeag), and red sandstone and conglomerate of Cambrian age, which cover a portion of the Eye peninsula and the shores of Stornoway Harbour at Arnish Point. The same deposits are continued north as far as Gress.

The Lewisian gneiss (Murchison's Fundamental or Laurentian gneiss) is generally coarse-grained and of a greyish pink colour. Occasionally, however, it assumes a finer texture and shows darker tints: and here and there it seems to pass into a kind of argillaceous schist and to contain interbeddings of several crystalline rocks, which, as far as my own observations went, appear to be merely varieties of the gneiss itself. In these rocks sometimes felspar, sometimes quartz forms the prevailing mineral; and with these are associated now mica and again hornblende. All the gneissic rocks in the island weather more or less rapidly. Below certain glacial deposits, I found them soft and friable to a depth of several feet; and even projecting knobs and bosses of harder rocks often showed on freshly fractured faces that weathering had likewise affected them for several inches from the surface.

As a rule the stratification of the gneissic rocks is well-marked, the beds having a prevalent north-east and south-west strike, with a south-east dip, generally at a high angle. In some places, however, the direction of dip changes to different points of the compass, and the bedding not unfrequently becomes crumpled, contorted, and obscure.

I mention these facts concerning the geological structure of Lewis merely to make clear the remarks which follow. My time spent in the island was fully occupied in studying the glacial

phenomena; and hence I have been able to add nothing to our knowledge of Lewisian petrology.

IV. *Glaciation of the low grounds of Lewis.*

As he approaches Stornoway from the sea, the glacialist cannot fail to observe that the rocky and broken ground along which he coasts, presents much of that same worn and mammillated appearance which forms so striking a feature in the coast-scenery of the western sea-lochs. The hills appear to be smoothed off, but, strange to say, *against* the general slope of the land, or, in other words, from the shore to the interior. But when the observer subsequently rambles over the same ground, the glaciated aspect which the rocks appeared to assume while viewed from the deck of the steamer, becomes much less conspicuous. Broken and irregular-shaped masses of gneiss, with confused and straggling hollows between, meet his eye on every hand. The rounded mammillated appearance has seemingly vanished; and he searches in vain for any striations. But as he makes his way towards the road leading from Stornoway to Luirbost, he becomes aware that the broken and rocky hills have a tendency to arrange themselves along a line stretching approximately north-east and south-west, and that for the most part they present an abrupt face to the north-west, with gentler and less broken acclivities sloping away in the opposite direction. In short, this rough ground consists of a series of interrupted and ragged escarpments of gneiss. It would have occupied much more time than I had at my disposal, had I tried to ascertain whether these escarpments owed their existence in the first place to any differences in the texture and durability of the gneiss. But from what I was able to make out, it appeared to me that such would very likely prove to be the case. At all events, of this there can be no doubt—namely, that the line of the broken escarpments answers precisely to the strike of the gneiss. These escarpments, as I have just said, face to the north-west; and the slope of the ground behind corresponds exactly with the *direction* of dip, but seldom, if ever, with its *angle.* A hasty observer of the dip and strike might therefore be apt to conclude that the appearance of glaciation as noted from the sea is delusive, and that what seem to be *roches moutonnées* are features due simply to strike and bedding. But one familiar with the phenomena of an ice-worn country would not fail to remark the presence of those peculiar flowing lines and flutings which mark the hills when these are viewed at a little distance. He would note, moreover, that the tops of the crags and knolls are rounded off in a way which is at least strongly suggestive of glacial action, and he could hardly doubt that the presence of a deposit of till in sheltered nooks and hollows between the hills was good evidence in the same direction.

I have referred to this barren rocky district because, owing to its accessibility from Stornoway, it is most likely to be the first visited by geologists who may think of going to Lewis. The appearance

of this district certainly does not seem to promise much for the interior; and one who shall limit his investigations of the glacial phenomena of Lewis to the neighbourhood of Stornoway will perhaps think the evidence there does not go a long way in support of the conclusions arrived at in this paper. In that district, where, as I have said, the direction of dip is right against that of glaciation, the latter can hardly be so striking as it would have been had the gneiss dipped in some other direction. But fortunately in other parts of the island the direction and angle of dip vary, while the trend of the glaciation never does.

The first unmistakably glaciated rock-face I met with in Lewis was on the side of the road leading from Stornoway to Gearaidh nah Aimhne, about a half-mile beyond Loch à Chlachain. It is a broad flat surface of gneiss, planed and smoothed, from which, however, the striæ have disappeared. A little further on, at Beinn à Bhuna, the watershed is reached amidst ruinous *roches moutonnées*. Here the glaciated and mammillated aspect of the rocky knolls is still more apparent, and the smoothed and glistening domes of gneiss seem to give promise of a plentiful crop of striæ. But, although I searched long, I found none; the treacherous gneiss had failed to preserve them. The rock at this place is for the most part coarsely crystalline. It occurs in masses irregularly jointed; and the bedding is either very obscure or altogether lost. The direction of the glaciation, however, as evinced by *roches moutonnées*, cannot be mistaken. It is as near as may be from south-east to north-west.

But perhaps the best display of *roches moutonnées* in Lewis, and certainly the most easily accessible, occurs along the borders of Loch Roag. Shortly after leaving Callernish, with its weirdlike Tursachan, the road enters a rough hilly tract in which every dome and boss of rock presents a finely mammillated surface. Here the direction of the glaciation is distinctly south-east and north-west, or the same as upon the watershed at Beinn à Bhuna and in the district of Arnish moor near Stornoway. The dip of the gneiss is moreover very variable, being sometimes north and north-east, the strata at the same time appearing highly crumpled and contorted. Occasionally, indeed, the bedding even vanishes altogether. In this district therefore the direction of the *roches moutonneés* cannot be ascribed to the structure of the gneiss. The slopes of the ground are evidently quite independent of the dip and strike of the rocks; and even were there no dome-shaped hillocks and mammillated knolls, we could hardly ascribe the peculiar conformation of the ground to any other agency than that of land-ice. Rock-faces innumerable were scanned for striæ; but although something like faint ice-markings occasionally appeared, none of these could be considered sufficiently pronounced. I was beginning to despair of finding any, when at last I stumbled upon a beautifully striated rock-surface from which the till had been recently removed. As this was the only distinctly scratched rock-surface I met with in the low grounds of Lewis, it may be as well to particularize the locality. It occurred in a little opening or quarry-hole close to the roadside

at the north end of Loch na Muil'ne, a few yards beyond the path leading to the village of Tolasdádh à Chaolais. The rock, which is a somewhat close-grained dark gneiss, was smoothed and polished over a space of several yards, and covered with long parallel striæ and grooves, which bore south-east and north-west, or precisely in the same direction as the *roches moutonnées.* It is unnecessary to add more about the glaciation of this district; but if any geologist should think of visiting this part of Lewis, I would advise him to follow the road as far as Carloway or even Delbeag. The glaciated aspect of the country is wonderfully impressive, and he will not fail to remark especially the fine *roches moutonnées* of the heights overlooking Loch Carloway.

About 2½ miles to the south-east of Delbeag some bare rocky hills, rising out of a sombre peaty moorland, form rather striking objects. They are not much over 800 feet high; but that height in the north of Lewis makes a considerable mountain. No one who examines them with any attention can doubt that they too have been rubbed by ice coming from the south-east.

Again, midway between these hills and Stornoway, rises Beinn Barabhais (900 feet), the dominant point in the north of Lewis; yet even this ridge of high ground exhibits traces of glaciation in the same direction.

Soon after reaching the watershed halfway between Stornoway and Gearaidh nah Aimhne the wayfarer catches his first glimpse of the mountains in the south of Lewis. The view is at once striking and instructive. Immediately at his feet lies a broad undulating moor, dotted here and there with patches of green meadow land, which only serve by contrast to render still more dreary the outlying desolation. Numberless lakes, as usual, are scattered over the whole expanse of moorland, which sweeps away to the south-west until it seems to end quite suddenly against the base of the mountains. The view of these mountains reminded me somewhat of the general appearance of the Moorfoot Hills (which, however, are infinitely tamer) as seen on a clear day from the top of Arthur's Seat —when they seem to rise abruptly out of the low grounds at the head of the Esk like a lofty rampart. The Lewisian mountains in the same way appeared to spring directly out of the moorlands, and to stretch in a straight line across the whole breadth of the island. When they are approached, however, it soon becomes apparent that the nearer hills are by no means so lofty as they looked when viewed from a distance. An approximately straight line drawn in a south-east direction from Aird Thoranish opposite the Great Bernera, through the district of Linshader, and so passing the heads of Lochs Erisort and Seaforth to the shores of Loch Shell, marks in a rough way the boundary between the low-lying moorland and bare rocky tracts of the north, and the mountains of the south. The moorlands adjoining this line do not average a greater height above the sea than some 200 feet, while the hills immediately to the south of it hardly ever rise above 800 feet or thereabouts. Now it is remarkable that these hills are not glaciated from the high grounds

behind them, but are distinctly ice-worn in the same direction as the whole of the northern moory districts—that is, from south-east to north-west. Nay some of the higher mountains themselves seem to be merely gigantic *roches moutonnées*. Such, at all events, appears to be the case with Suainabhal, whose bare rocky head and sides strongly suggest that the whole mountain from base to summit has been smothered in ice that moved outwards to the Atlantic; but a particular account of the mountain tracts of Lewis and Harris is reserved for a future paper. I shall only remark at present that all the principal valleys in the western districts of the Lewisian mountain region trend north and north-west, only a few streamlets finding their way down the southern slopes of the hills into Loch Resort, while no valley of any consequence opens out upon the low grounds that stretch away to the north-east. In the southern or, rather, south-eastern mountain districts, the valleys radiate to various points of the compass, and one of considerable size, occupied by Loch Langabhat, expands into the low grounds. Notwithstanding this, however, the direction of the glaciation over these low grounds is in no wise affected. The *roches moutonnées* still sweep persistently along the base of the mountains from south-east to north-west.

It thus becomes evident that the ice which passed from sea to sea across the whole breadth of the low grounds of Lewis did not come from the southern mountain tracts. And it is no less evident that this ice was of sufficient thickness to keep on its course towards north-west undisturbed by the pressure of the glacier masses, which must at the same time have filled to overflowing the deep glens and valleys of the mountainous region referred to.

Some further account of the glaciation falls to be given when I come to consider the origin of the freshwater lakes.

V. *Bottom Till of the low grounds.*

Throughout all the low grounds of Lewis we find a deposit of till lying in the valleys, nestling in hollows between *roches moutonnées* and stretching more or less continuously for long distances over gently undulating flats. The materials of which this deposit consists appear to be derived almost exclusively from the degradation of gneissic rocks. The paste, or matrix, is generally a dark or light reddish brown hard clay, frequently rendered coarse and gritty by the quantity of gneissic matter diffused through it. Indeed to such an extent is this the case that in some places the matrix partakes more of the nature of an earthy grit than of clay. It exhibits an abundance of blunted angular and subangular fragments of gneiss, varying in size from mere grit up to boulders several feet in diameter; but boulders of a large size do not occur very frequently. The largest one I saw measured only $5\frac{1}{2}$ feet across, and was estimated to contain about 70 or 80 cubic feet. It would be difficult to give an average size for the stones. They seemed not to differ in dimensions from the boulders in the till of the Scottish Lowlands—stones measuring from 2 or 4 to 6 or 8 inches across being per-

haps most numerous. In some places the stones are so closely aggregated as to give to the deposit the appearance of a very coarse angular shingle. By far the greater majority consist of gneiss; and I did not see a single stone in what (to distinguish it from certain other stony clays) I have called the "bottom till," which might not have been derived from the rocks of Lewis itself. At the Butt, however, I detected a number of red-sandstone boulders lying loose in the fields, which are most probably derived from the subjacent till, and which could hardly have come from the Cambrian district near Stornoway. Red sandstone, however, may occupy the sea-bottom at no great distance from Cellar Head; and hence we are not compelled to suppose that these sandstone fragments have travelled from the mainland. At Barabhais, again, the sea-beach is strewn with fragments of the same rock intermingled with boulders of gneiss. These, I do not doubt, are derived from the wreck of a stony clay, some portion of which is still seen along the sea-coast of that neighbourhood. The red-sandstone fragments may quite well have come from the Stornoway district, which lies to the south-east of Barabhais.

In shape, the stones and boulders of the bottom till exactly resemble those of the Scottish Lowlands, and constantly show that peculiar blunted form and smoothed surface which are so characteristic of glacial work. Few, however, exhibit any striæ. The harder- and finer-grained rocks, it is true, are almost invariably scratched; but rocks of this kind do not abound. The comparative absence of well-scratched stones, however, is quite in keeping with the rarity of striated rock-surfaces. For both we have doubtless to thank the lithological character of the gneiss itself. In further proof of this I may remark that the fragments of granite and gneiss that occasionally occur in the till of the Scottish Lowlands, even so far south as the valley of the Irvine, seldom or never show striæ, although they are otherwise well glaciated.

The Lewisian till is quite unstratified. Many hundred sections were examined; and only in one instance did any thing like stratification present itself. This was in a cutting made for a stream that issues from Loch Airidh an Eipe, four miles west from Stornoway. The section showed a deposit of the usual unstratified till, with a number of striated stones, and two distinct lines of boulders, some five or six feet apart. I may also add that at several points along the south-east coast of the peninsula of Eye a bed of gravel and rolled stones comes between the till and the subjacent gneiss.

It is impossible to say what depth of this bottom till there may be in Lewis; but as a rule it does not seem to exceed a few feet. In stream-sections and quarry-holes it varied in thickness from 5 or 7 to 12 feet, but occasionally it reached as much as 15 or 20 feet. Underneath the deep covering of peat which hides so much of the flat and gently undulating low grounds, its thickness may be considerably more.

A close search for fossils failed to detect the slightest trace of any thing organic.

Owing to the abundant presence of gneissic grit in the till, this deposit weathers rapidly; and the face of a section must soon become concealed behind a curtain of coarse-grained gritty sand. For the same reason, the decomposition and breaking up of the till all over the country often gives to the ground the appearance of being sprinkled with morainic débris. I satisfied myself, however, that this moraine-like matter was merely the weathered upper surface of the till, or the wreck of that deposit commingled with the débris of the underlying gneiss.

Some interesting sections of till are obtained along the south-east coast of Eye Peninsula, near the village of Phabaill. Here it forms in places an irregular terrace sloping to the sea. In other places in the same neighbourhood it lies in hollows between the cliffs, or is scattered over the hill-sides. We get it also on the very crest of the lofty sea-cliffs themselves, where it occasionally attains a considerable depth. Examples of this occur at Bagh Phabaill Iosal and at Leabaidh a Mhinisteir, near the Chicken Head, at which last-named locality a bed of rolled stones underlies the till. Here also the highly weathered and decomposed character of the gneiss below the drift is well seen.

Along the courses of such streams as cut down through the thick peat good sections of till are frequently exposed. It is perhaps hardly worth while to refer to any special example; yet mention may be made of the Gleann Mòr Barabhais and some of its small tributary streams, as, for instance, Roundograth, where an excellent exposure of till is seen, a little above where the road crosses the water. The Amhuinn a Ghlinn Diubh, the Amhuinn Ghriais, and the river Laxdale also show similar cuttings. But the geologist need never stray far from the roads for good opportunities of studying this kind of drift. He will find it laid open in numerous holes and pits in every part of the island, where it is used for making and repairing the roads—a use to which the much more argillaceous till of the Scottish Lowlands could not be put.

As far as my observations went, the bottom till did not seem to form any distinct feature in Lewis. It appears to lie thickest in the valleys and in sheltered hollows, especially in front of such knolls and broken escarpments as face to the north-west. Occasionally, however, it sprinkles the surface of exposed hill-slopes. But the low-lying flats are usually so thickly covered with peat that the configuration of the drift is entirely concealed. In some valleys I thought I could detect a terrace-like arrangement of the till similar to that which is so characteristic a feature of the Peeblesshire till. Thus along the Amhuinn Theidagul, near Carloway, the till seen from a little distance appeared to form a terrace sloping with the slope of the valley, and dipping gently in towards the stream; but a nearer inspection, if it did not quite dispel, certainly rendered this appearance much less conspicuous.

In the north of Lewis there occur two more recent deposits of stony clay, the lower of which is fossiliferous, and separated from the upper by beds of gravel, sand, and clay, also containing fossils;

but all description of these is reserved until, in a future communication, I come to treat of the younger glacial accumulations of the Long Island.

VI. *The Freshwater Lakes of Lewis.*

A glance at the general trend of these lakes is enough to convince one that large and small sheets alike have a strong tendency to assume a linear direction, and that by far the greater number are arranged along one or the other of two lines, which strike as near as may be north-west and south-east and north-east and south-west respectively. It even happens pretty frequently that the same loch exhibits in itself both lines of direction, one portion of the water trending at right angles to the other. In the mountain district of the south a number of important lakes occur which do not coincide in direction with either of the series just referred to, but extend sometimes north and south, sometimes east and west. The origin of these three groups of lakes has now to be considered.

a. North-west-and-south-east Lakes.

With one exception all the longest and most considerable lakes range in a direction from south-east to north-west. The group to which these belong is most abundantly developed over the low-lying rocky and moory region that extends across the whole island, from the district of Pairc to the broken tracts around Loch Roag. North of Beinn Bharabhais they occur but seldom, and none are very strongly pronounced; indeed it is not unfrequently difficult or even impossible to say what is the prevailing direction of the lakes in that section of the island. But over the whole of the rocky and swampy low grounds that abut upon the southern mountains, the north-west-and-south-east lakes are not only exceedingly plentiful, but they are also well marked. They extend in long lines, often for a mile or two, with an insignificant breadth; and not unfrequently several lakes are joined together by narrow necks of water. Their shores are sometimes perfectly straight, but are oftenest very irregular, being indented with numerous lilliputian bays and creeks. These indentations, however, are quite subordinate to the trend of the lakes. I may add also that the numerous small runnels that flow into these lakes, and sometimes out of one lake into another, have for the most part the same trend as the lakes themselves. When this is not the case it will be found that the sluggish streams creep in precisely the opposite direction (that is, from south-west to north-east, or *vice versâ*); and those parts of the lakes into which such streams enter, show very generally a similar trend.

Most of these lakes, especially in the district under review, are very shallow; but in the rocky tract on the northern borders of Loch Roag they seem to be deeper. Many of them contain islets.

The shores of not a few I found to consist entirely of peat-moss; and in some places the peat seemed even to extend for some distance into the water. Occasionally, however, the borders of the lakes would exhibit till and rocky débris, with here and there the solid

rock appearing; while in yet other instances the water rested in complete rock-basins. Some good examples of the latter will be found in the district south of Loch Carloway.

Whatever theory we may form as to the origin of these lakes, it will probably be admitted that their linear direction is directly due to the configuration of the underlying rocks and till. We cannot suppose it likely that their peculiar shape has been produced by the gradual encroachment of the surrounding peat-mosses upon pre-existing lakes, which may at one time have shown quite a different outline. Again, if any of the lakes do rest throughout upon a bed of peat-moss (and I am far from denying that such may be the case), still we must admit, as it seems to me, that the lacustrine depressions or hollows existed before the peat; for the growth of a bog is regulated by the supply of water received, and this, again, is obviously controlled by the configuration of the ground. The hollows, therefore, cannot be in the peat, but in the surface upon which the peat rests. And that surface consists either of rock or till, or of both together.

While describing the glaciation of Lewis I confined my remarks to the appearance presented by hills and rocky knolls; and these prominences, as I showed, are distinctly ice-marked from south-east to north-west. Now the hollows occupied by the lakes I take to have been formed at the same time as the *roches moutonnées*. They occur, as may be seen, either in solid rock, or in till, or, lastly, in both. When the ice that swept across Lewis finally vanished it left as marks of its power not only rounded and fluted hill-tops, but hollows scooped out in the solid gneiss. The till that accumulated below the ice was also at the same time found arranged in long parallel banks, running in the exact direction followed by the ice-striæ and *roches moutonnées*. The arrangement of the till into long parallel mounds is a feature with which I have long been familiar. It is admirably displayed in the valley of the Tweed, in Nithsdale, and other wide dales and straths in the south of Scotland; and precisely the same appearance characterizes the deposit in Ireland *.

The north-west-and-south-east lakes, then, rest in true rock-basins, and also in hollows between parallel banks formed wholly of till or partly of till and rock.

b. North-east-and-south-west Lakes.

The north-east-and-south-west lakes, while resembling in general appearance those of the group just described, are, as a rule, more compact in form. They are also, for the most part, sharply marked off from each other, and seldom occur in those long straggling chains so characteristic of the north-west-and-south-east group. They are best developed in the district west and south-west from Stornoway, but appear also in considerable numbers intermingled, and in many places coalescing with the north-west-and-south-east lakes on the low grounds between Loch Roag and Pairc. None of them, as far

* See 'The Glaciation of Iar-Connaught,' &c., by Messrs. G. H. Kinahan and M. H. Close: Dublin, 1872.

as I could judge, are of any depth. The more strongly pronounced lakes frequently rest at the foot of well-marked escarpments, and sometimes in broad hollows between long parallel banks of gneiss. Their shores are frequently mossy all round; again they are often skirted by till and rock; but I saw no true rock-basins among them.

The trend of these lakes is obviously due to the structure of the ground, and has nothing to do with encroachments of peat. They coincide in direction precisely with the strike of the gneiss; and when any decided variation in the strike of the gneiss takes place there is a similar change in the direction of this group of lakes. This is well seen immediately to the west of Stornoway, where the lakelets are observed to follow the strike, which is at first east and west, gradually wheeling round to south-west.

The explanation of their origin appears to be simply this. The land-ice in its progress over the island had to encounter a series of low, rough, and interrupted escarpments. Flowing against the dip of the gneiss the stream would tend to deposit till in front of the cliffs, knolls, and rocky ridges that faced to the north-west. But the deposition of this till would be very irregular; and consequently, when the ice finally melted away, the hollows between parallel ridges of rock would be found unequally coated with ground-moraine. There would thus be ready for occupation numerous hollows with a prevalent north-east and south-west trend. As a matter of fact I found that the ends of such lakes, when not obscured with peat, were dammed up either wholly with till, or with till and rock together.

The manner in which the two groups of lakes now described frequently unite offers no difficulty. In many places the old strike-escarpments have been cut across by the ice at right angles; and thus a new system of ridges and hollows has resulted. Hence it is not surprising to find that not only lakes but also streams exhibit both directions—now trending north-west and south-east, and then turning sharply off at right angles to the course previously followed.

Besides the two groups of lakes now described there are some shallow sheets of water which, as already remarked, have no determinate direction. But these we can hardly separate from the others. They owe their origin either directly or indirectly to the glaciation. A few, however, may lie in shallow depressions dammed up by peat.

c. *Lakes of the Mountain Region.*

These, with some exceptions, are all due to glacial erosion. But it will be more convenient to give an account of them and the large sea-lochs—Resort, Seaforth, Claidh, and Bhrollum—when I come to treat of the glacial phenomena of Harris.

VII. *Conclusion.*

From the facts now advanced it is evident that Lewis has been traversed from south-east to north-west across its whole breadth by

glacier-ice. The ice with which the mountain-valleys of Harris and the south were filled had no share whatever in the glaciation of the northern part of the island, extending from the base of the mountains to the Butt, a distance of not less than 35 or 40 miles. Where, then, did the ice come from which overflowed this by far the largest portion of the island? There is only one place whence it could have come—the mainland. Standing on the watershed of the island and looking away towards the south-east (the direction from which the ice moved), the observer sees on the edge of the horizon the mountains of Wester Ross fringing the eastern borders of the Minch. It was amongst the wild glens of that distant region that the glaciers which overflowed Lewis were nourished. Loch Broom, Loch Greinord, Loch Ewe, Loch Gairloch, and Loch Torridon have each, as their severely glaciated mountain-slopes attest, brimmed with ice that flowed outwards to the Minch. So likewise the Outer and Inner Sounds of Raasay formed the channels of gigantic glaciers. The Island of Raasay, as my brother has shown, is glaciated from end to end. So is the Island of Rona; and the land-ice which did the work must have attained a prodigious thickness. The depth of the Inner Sound, between Raasay and the mainland, is not less than 120 fathoms, while off the coast of Rona it is as much as 138 fathoms. Now the height to which one may trace a *moutonnée* surface in Raasay is not less than 1300 or 1400 feet, which gives a depth of ice in the Inner Sound of upwards of 2000 feet; I believe, however, it was more than even that. The extreme height reached by the ice along this north-west part of Scotland has not yet been determined. The upper portions of the mountains, formed of Cambrian sandstones, have suffered much under the action of the weather; and while the tougher gneiss below still shows a finely mammillated surface, the overlying horizontal beds of sandstone, riven and shattered by the frost, have failed in great measure to preserve any distinct traces of glaciation. A detailed examination of that most interesting region would, I have little doubt, enable us to carry the surface of the old *mer de glace* up to a height of at least 3000 feet above the present sea-level: certainly on the mainland (as, for example, on the mountains overlooking Loch Torridon) *roches moutonnées* reach a considerably greater elevation than even the highest point in the Island of Raasay.

But let us take only the thickness I have given for the ice in the Sound of Raasay, as approximately that of the *mer de glace* that flowed into the Minch. The average depth of the Minch not being more than between 50 and 60 fathoms, it is evident that no part of our ancient *mer de glace* could have floated, but the whole mass must have pressed on over the bottom of the sea, just as if that had been a land surface. That the ice did not flow northwards up the Minch shows that an equally massive ice-sheet was at the same time streaming out from the deep fiord-valleys of Sutherland. The only course it could possibly take was precisely that which we know it did take—namely, across the broad low grounds of Lewis. Moreover the height to which Lewis has been glaciated leads irre-

sistibly to the conclusion that the great ice-sheet did not stay its onward march until it reached the edge of the 100-fathom plateau, some 45 or 50 miles beyond the Outer Hebrides, and calved its icebergs in the deep waters of the Atlantic.

Discussion.*

Prof. Owen corroborated the author's views as to the grand marks of glaciation on the island of Lewis, which had come under his personal observation.

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5. *Notes on the* Glacial Phenomena *of the* Hebrides. By J. F. Campbell, Esq., F.G.S.

As I shall be unable to be present at the reading of Mr. Geikie's paper on the Glaciation of the Outer Hebrides, I beg to submit to the Geological Society some extracts from my journals containing observations on the glacial phenomena presented by the western islands.

Tiree, Sept. 1871.—The island is flat; and the low grounds appear to have been under water. The highest hill is Heynish, at the south-west end, and 500 feet high. On the top of the hill are a great many large perched blocks; some are 14 or 15 feet long. So far as I could make out, they came from the north-west; they are chiefly gneiss, like rocks in the outer islands. The rocks are glaciated and weathered.

Harris, Sept. 17.—The hills are made of contorted Laurentian gneiss, and much glaciated, but weathered. So far as I could make out, the ice came from N.N.W. through a gorge at Tarbet.

Bernevay to Barra.—Bernevay is the last of the Hebrides; the whole chain looks like the hill-tops of a drowned continent. The separate islands are rocky and grassy, and are about 1000 feet high or less. On the east side these hills slope down to the Minch. On the west the Atlantic has battered the hills, and broken them, so that great cliffs now plunge sheer down, or overhang the sea. Where the rock is soft, the Atlantic waves dig into it, and make sea-caves, and there work mischief till the roof comes down. Then a rift cuts eastwards into the mountain, and becomes a "ghà," in which the sea-birds abide. The structure of the rock is seen in these great cliffs as in a geological model; and the way in which the surface-forms are carved out of the solid is as plainly seen as in the grain of a wood-carving. Whatever denuding engine was the most efficient here, certain it is that ice had a great deal to do with this

* A telegram was received from Dr. Bryce on the day of the Meeting, which, owing to a misunderstanding as to its object, was not read at the Meeting. It was to the effect that Dr. Bryce had satisfied himself from observations made in Lewis, Harris, and North Uist, and had published his opinion last year, that the ice which produced the glacial markings in those islands had come from a land to the westward, since submerged. This view nearly coincides with that advocated by Mr. J. F. Campbell in the following paper.

work. But the rock weathers easily, and striæ are not easy to find; all the marks that I found came from the north and west, not from the eastward as I had expected. But the most of these fresh marks are in hollows between hills, where the moving power, if water, had to follow the land, as tides now do in sounds. It seemed to me that sea-ice did the last of the grinding in these regions, and that tides were the moving power when the land was submerged more than it is.

At Barra Head, on Bernevay, I got marks at 720 feet up, from N.N.W. magnetic, crossing the strike of the rock, on a "tor" near the old fort, close to a cliff whose edge is at the hill-top. A great many travelled blocks are on the island, scattered about the hill-side, at levels higher than the top of Heynish in Tiree, 500 feet.

Minglay.—The next island north of Bernevay is about three miles long, a mile wide, and a thousand feet high. The west side is a cliff 900 feet high, with a rift cutting into the hills; it ends in a cave, which is said to reach nearly to the sea on the east coast.

I stood on one side of the rift, and looked at the opposite wall 900 feet high. On the east side from the verge of the cliff the island is a wide valley sloping down to the sea, and to a sandy beach. The inhabitants climb like monkeys, and go wherever there is holding for hands, after eggs and birds. Large loose stones are on the ridge of this island, which is one of the strangest places in these realms.

I did not land upon the islands between Minglay and Castle Bay in Barra; but I coasted along them, and saw how the waves have dug out whin-dykes, so as to leave long narrow rifts with vertical walls. Through these boats pass in very calm weather. These were "faults," or breaks in the strata; but they were filled with "dykes;" for remnants of dykes are left here and there, and make natural bridges, under which boats pass. I walked over one in Minglay, and looked down 550 feet into the sea, and at a bit of the double whin-dyke, which makes this bridge, and another bridge lower down. The rest of the dyke is under water at the bottom of the rift, and the chasm is a bit of marine denudation.

Barra.—At Castle Bay, in Barra, glacial striæ are well preserved at the sea-level, near some boulder-clay. Sept. 24, 1871, I took several rubbings. The direction is from north by west, magnetic, about N.N.W. true. The ice came through a hollow; on the watershed of the hollow, and on the western coast, and right up to the hill-tops, all the country is glaciated; and perched blocks are strewn all over the island of Barra. Boulder-clay and drift make the soil.

South Uist, Sept. 28, 1871.—I drove up the road, and took rubbings from glaciated rocks by the wayside:—1. At Birsdale, on the west side of the hills, in a quarry by the roadside, striæ ran from north 40° west magnetic, pointing at a gap in the hills.

2. About halfway up the island, about 100 feet above the sea-level, in the flat country on the west side of the hills, near a large perched block, from north 52° west magnetic was the direction, and the grooves point at a gap in the chain of hills.

3. Near the north end of the island, not far from the hills, on their western side, out in the flats, the direction was north 65° west, magnetic.

4. Near the chapel at Jochdar, on the northern corner, close to the sea, at the sound of Benbecula, crossing the strike of the rocks, it was north 65° west, magnetic.

The last two sets of marks are parallel to the run of the tides in the neighbouring sound. The Cuilin Hills in Skye were seen from the spot; a stick laid in a groove pointed directly at these hills, distant about forty-five miles beyond the Minch. The hills on the eastern side of this island are all glaciated from top to bottom; and perched blocks abound. I saw them from the steamer with a good telescope; but I have not been up these hills.

Benbecula is a flat island, with a single rocky hill in the midst of it. I found no striæ; but all the rocks are glaciated, as in the other islands. Boulders and boulder-clay and drift abound under peat-mosses.

North Uist.—The whole of this island is glaciated like the rest; at Loch Maddy, on the east coast, and the northern corner, next to the sound of Harris, the direction is nearly the same as in South Uist, about north 45° west. Drift and boulder-clay are on all the low grounds; perched blocks and boulders are on all the higher grounds, so far as I could see with the glass. At the north end the strata are nearly vertical; and the shape of the surface of the country bears no relation to bedding or faults, or contortion of beds. The hills and hollows are carved out of the solid.

Skye.—In the north end of Skye, between Dunvegan and Port Portree, the rocks are igneous. Amongst these brown rocks I could not find one single specimen of the grey and glittering boulders which are strewn all over the outer islands.

In the outer islands I do not remember to have found any boulders like the rocks of Skye. In 1871 I wrote:—

"Like many a better man, I am at fault; but, on the whole, I incline to think that the last glacial period was marine in these parts, and that heavy ice came in from the ocean and ground the hollows in the Long Island by help of tides, which ran as tides now run in the sounds." If so, this part of the world was then in the condition of Labrador. There glaciers do not grow on shore, but heavy icebergs and great floes pass along the coast southwards, and ground in shallows and in sounds among firths and islands.

Since then I have been over Ireland; and the result is in the May number of the Journal (No. 114), to which I beg to refer. The glaciation of the United Kingdom must be treated together as part of a larger system, according to my opinion.

Lakes, &c.—The hollows which hold water in the outer Hebrides are so numerous that they must be counted by thousands. Some are peat-holes; some are made by artificial or natural dams; but the most of them are rock-basins. I believe these to be part of the general glaciation of the country. Where these basins are near the edge of a cliff, it is seen that the hollow above is the result of wearing

and waste, not of subterranean movements or fracture. The cliff-sections demonstrate that the hills also are carved; and vertical sea-cliffs prove that the sea does not carve rounded hills. In islands a few miles square there are no streams to account for large rounded hollows a mile wide and a mile long. As glacial marks are in the hollows, they must have been filled with ice; but in the Hebrides the ice appears to have come from the direction of Greenland, at same late time. Questions are:—What kind of ice was it? over what area did it ever extend? and what work did it do? How came these hills and hollows to be carved into their present rounded forms?

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6. *On the* Older Tertiary Formations *of the* West-Indian Islands. By P. Martin Duncan, M.B. Lond., V.P.G.S., F.R.S. &c., Professor of Geology in King's College, London, &c.

[Plates XIX.–XXII.]

In 1867 I believed that I had concluded the examination of all the collections of fossil corals from the West-Indian Islands which were available, and I was not aware that any others were likely to be formed. Therefore in a communication to this Society, which was published in the Quart. Journ. Geol. Soc. vol. xxiv. p. 9, after having been read Dec. 4, 1867, I summarized the results of some years' labour on the subject.

In the winter of 1868–1869, Mr. P. T. Cleve, a Swedish mineralogist and geologist, undertook a geological investigation of the North-eastern West-Indian archipelago. He visited the Virgin Islands, St. Bartholomew, Anguilla, St. Martin, Saba, St. Eustatius, and St. Kitts, and spent a short time in Puerto Rico. After making collections of minerals and fossils, he returned home, and communicated a paper on the geology of the North-eastern West-Indian Islands to the Royal Swedish Academy on November 23, 1870.

This communication consists of the descriptive geology and mineralogy of the islands, with a few notices of the fossil forms. The palæontology of the more important islands remained untouched; and early in the year 1873 Mr. Cleve asked me to help him in the matter.

Some weeks since I received a great number of fossil corals, which had been collected with care, and which belong to the University of Upsala and to the collector.

A cursory examination of the great collection was sufficient to prove its importance; for it contained abundant evidence of the former existence of a grand reef-area in the Northern Caribbean Sea, prior to the Miocene, and after the Cretaceous period.

The study of the specimens has enabled me to fill up the hiatus in the history of the old reefs of the Caribbean, which was rendered apparent by the publication by Mr. Wall and myself, in our communication on the geology of Jamaica, of the traces of a coralliferous Eocene series.

The specimens obtained by Mr. Wall from the conglomerate series

overlying the Hippurite limestone in Jamaica were small, stunted, and indifferently grown; but those now under consideration are large, numerous, and indicate the former existence of all the physical conditions peculiar to coral-reefs.

Influenced by these considerations, I thought that another essay on the subject which has so frequently been brought before you would still be interesting.

Strata which could be correlated with European Eocene deposits were discovered by Mr. Lucas Barrett when surveying Jamaica. He found some conglomerates in one part of the island, and dark shales and sandstones in others, overlying the Cretaceous formation, and covered by deposits which had been determined to be of Miocene age; but the palæontological evidence was deficient.

In 1864 Mr. Wall and myself contributed to this Society the paper already noticed; it contained his description of the stratigraphical succession, and my notice of the Madreporaria. These had the facies of the older Tertiary deposits of the Old World; and the specimens recalled the puny development of the corals of the London Clay and Bracklesham deposits.

The notice of the Madreporaria was summed up as follows:—"The Eocene shales and dark-coloured sands which represent the conglomerate in some localities, or which constitute its upper part in others, yield corals in no very great number. The specimens from Port Maria are either dark and carbonaceous-looking, or are contained in a fine dark purple conglomerate. All are very significant of the horizon, and recall the puny development of the species of the London Clay. The *Paracyathus* from Yallahs Valley resembles that of the London Clay, being even stained black, like the Sheppey specimens. The *Stylocœnia emarciata*, Ed. & H., is a well-known form in British, French, Italian, and Sindhian early Tertiary collections, and the *Stylophora contorta*, Leymerie, also. The *Stylocœnia* and *Stylophora* are characteristic corals, and denote an Eocene horizon; and they indicate, when unaccompanied by other species, the existence of physical conditions not favourable for coral-growth."

In 1867 I added *Columnastræa Eyrei*, nobis, to the Eocene coral-fauna of Jamaica.

Mr. R. J. Lechmere Guppy, F.G.S., in 1866, suggested that the San-Fernando beds might belong to a formation of older date than the superincumbent Miocene strata. They were evidently younger than the Cretaceous formation; and their Brachiopoda presented a facies which might be considered either Tertiary or Cretaceous. Still no characteristic Eocene species was discovered in Trinidad.

Nevertheless Mr. Guppy's sagacious idea has borne good results; for Mr. Cleve found the San-Fernando *Echinolampas ovum-serpentis*, Guppy, and *Ranina porifera*, Woodw., in some strata in the Island of St. Bartholomew.

These strata have yielded the fossils about to be described, and which belong to a pre-Miocene fauna. Moreover Mr. Cleve has found in them many specimens of a large *Nerita* allied to *Nerita conoidea*, Lmk., and also *Cerithium giganteum*, Lamk.

The Island of St. Bartholomew, situated in 62° 51′ 6″ W. long. and 17° 53′ 50″ N. lat., is a narrow island, about 10 kilometres in length. It is mountainous; and the soil is very stony, rock-fragments and boulders existing everywhere, and proving the great denudation which has gone on for ages.

The rocks consist of:—a fine-grained claystone, which has been tilted up by a syenite porphyry; of an immense depth of igneo-sedimentary rocks, consisting of tufas and breccias; of conglomerates, which include portions of the breccias; and of limestones, which are covered by and rest upon members of the igneo-sedimentary series.

The limestone is a very hard and compact rock, with a flat even cleavage. It has a decided tendency to break in parallelopipedal or cubic pieces; and the fissures generally contain fine crystals of calc-spar. Usually the fossils included are badly preserved.

Resting on unfossiliferous conglomerates, breccias, volcanic tufas, and scoriæ, and being covered by similar beds, there is no stratigraphical guide to the age of the limestones. They dip at no very great angle, and have suffered great denudation in some places, and much chemical change universally.

Near the contact of the conglomerates and limestones, rounded concretions of grey limestone, with fossils, are found.

All the Madreporaria which were collected and sent to me are heavy, usually well preserved, and dark grey in colour. In their aspect they resemble Silurian fossils; and in mineral condition they are totally unlike those found in any of the Miocene formations of the West Indies.

The corals consist of a carbonate of lime which has replaced the original hard tissue and infiltrated into the interstices, where it is usually crystalline. Sometimes the outsides of the fossils consist of granular or amorphous carbonate of lime, and the insides are crystalline. In other specimens even the linear septa have been replaced by minute dark crystals.

The specimens include simple or solitary forms, and true reef-building types.

The latter are large, and parts of them are well preserved.

No Miocene deposits exist on the island; and the so-called Pliocene is absent.

The limestones and the concretionary rock contain both of the types of coral (simple and compound); and whilst the branching forms give evidence of having been broken off with violence, and of having been rolled, the simple forms are usually very perfect.

The fossiliferous deposits appear therefore to have collected outside a reef, and in moderately deep water—the floor of the sea having been the natural habitat of the numerous simple corals, and having also been the area for the accumulation of volcanic ejectamenta.

Description of the Species.

MADREPORARIA APOROSA, Edw. & Haime (1857).

Family TURBINOLIDÆ.

1. Flabellum appendiculatum, Brongniart, sp.

A small specimen of this species, which resembles the one from Crosara, in the Castel-Gomberto district, is amongst Mr. P. T. Cleve's collection from St. Bartholomew's. It differs from the type in having a larger pedicel.

The species was first described by Brongniart, in 1823, under the genus *Turbinolia*; and subsequently Bronn and Milne-Edwards & Jules Haime placed it in the genus *Flabellum*. It belongs to a group which characterizes the Eocene formation of Biarritz and Ronca.

Family OCULINIDÆ.

Division Stylophorinæ, Edw. & H.

1. Stylophora compressa, spec. nov. Pl. XIX. fig. 5.

The corallum is ramose; and the branches are flattened out, but thick.

The cœnenchyma is well developed; and there is much space between the corallites in some parts, and less in others. It is very faintly granular, and is marked by a ridge which meanders between the calices, and includes them in more or less geometrical meshes.

The calices are small, and are surrounded by a raised rim, which is rather wavy.

Six principal septa reach the small styloid columella. The other septa are rudimentary.

Loc. The limestone of St. Bartholomew's, West Indies.

In the collection of the University of Upsala, and of Mr. T. P. Cleve, of Stockholm.

2. Stylophora distans, Leymerie, sp.

3. Stylophora conferta, Reuss.

4. Stylophora tuberosa, Reuss.

These species were noticed by Reuss in the Coral-fauna of Monte Grumi and Montecchio Maggiore, and are represented in the limestone of St. Bartholomew's, as are also *Stylophora granulata*, Duncan, and *Stylophora affinis*, Duncan.

These last two forms are members of the Caribbean Miocene Coral-fauna—the first having been described by me from the Jamaican, and the last from the Antiguan deposits.

The genus is extant in the present reefs of the West Indies; and all the species are closely allied.

Family ASTRÆIDÆ.

Division Trochosmiliaceæ, Edw. & H. (1857).

1. Trochosmilia subcurvata, Reuss. Pl. XIX. fig. 1.

A variety of this species is present in the St.-Bartholomew limestone; and it has a very great resemblance to the type which came from Oberburg, in Styria, and was described by Reuss in 1864*.

Var. nov. Pl. XIX. fig. 1*a*.

The corallum is subturbinate, and rather sharply conical inferiorly: its curve is slight.

The calice is widely open; and the septa are thin, long, and crowded. There are five cycles of septa, the fifth being complete in some of the six systems.

The costæ are subequal above, not very prominent, and faintly granular. Accretion-ridges are seen.

Loc. Island of St. Bartholomew.

Collection of Mr. P. T. Cleve, Stockholm.

2. Trochosmilia insignis, sp. nov. Pl. XIX. fig. 2.

The corallum is tall, cylindrical above, and curved inferiorly. Superiorly it is slightly compressed, and inferiorly decidedly so, close to the broad scar of the former adhesion.

Transverse sections near the calicular termination exhibit nearly circular outlines.

The wall is thin; the costæ are subequal, distinct, sharp, not crowded, and they enlarge where the exotheca comes in contact with them. Near the calice rudimentary costæ exist.

The septa are thinner than the costæ, and are wavy. There are six systems, and five cycles in each system, the fifth being occasionally incomplete. Septa are attached to the rudimentary costæ. All the septa are connected by oblique dissepiments; and a false columella is occasionally produced by the junction of the septal ends by endotheca.

The exotheca is abundant.

Height of corallum $1\frac{7}{10}$ inch. Breadth of section $\frac{6}{10}$ inch.

Loc. St. Bartholomew's Island, West Indies.

Collection of Mr. P. T. Cleve, Stockholm.

Var. with equal costæ.

3. Trochosmilia arguta, Reuss. Pl. XIX. fig. 3.

Some specimens from the limestone of St. Bartholomew, and in the collection of the University of Upsala, so closely resemble this species† from the Castel-Gomberto Oligocene that I am disposed to consider them geographical varieties.

Var. with a few more costæ than the type.

* Reuss, Denkschr. Akad. Wiss. Wien, math.-nat. Cl. Band xxiii. 1864, p. 13, and Band xxviii. 1868, p. 140.

† Reuss, Denkschr. Akad. Wiss. Wien, math.-nat. Cl. Band xxviii. p. 140.

Division ASTEROSMILIACEÆ, Duncan, Phil. Trans. 1867.

Genus ASTEROSMILIA, nobis, Phil. Trans. Royal Society, 1867, p. 653.

The corallum is simple, long, and more or less horn-shaped. The costæ are irregular in their development, many being crested. The septa are numerous and exsert. The columella is more or less solid, essential, and compressed. Pali exist. The endothecal dissepiments are distinct, tolerably numerous, and curved.

1. ASTEROSMILIA POURTALESI, spec. nov. Pl. XIX. fig. 4.

The corallum is slightly curved and compressed. The calices are elliptical in outline. The columella is short, stout, and lamellar. The septa are numerous, close, and thin; there are five cycles of them, and the fifth is incomplete in some systems.

The costæ are numerous, and alternately large and small.

The endotheca resembles synapticulæ; and there is an epitheca. Exotheca well developed.

Height of corallum 1 inch. Length of the calice $\frac{5}{10}$ inch.

Loc. In the conglomerate of St. Bartholomew's, West Indies.

In the collection of Mr. P. T. Cleve, Stockholm.

Division STYLINACEÆ, Ed. & H.

1. STYLOCŒNIA EMARCIATA, Lamarck, sp.

A specimen of this well-known form was found in the limestone of St. Bartholomew's, West Indies.

1. STEPHANOCŒNIA INCRUSTANS, spec. nov. Pl. XX. fig. 6.

The corallum is low in height, and incrusts rocky surfaces.

The corallites are united by their rather thick walls, and are parallel.

The calices are quadrangular or pentangular, and their margins are marked by the septa of the adjacent corallites.

The septa are subequal at the wall, and 16 in number; but only eight reach the small and deep styloid columella; the others project very slightly, and are moniliform on their free edge. The pali are attached to the eight larger septa.

Height of corallum $\frac{1}{10}$ inch. Breadth of calice $\frac{1}{20}$ inch.

Loc. In the limestone of St. Bartholomew's.

In the collection of Mr. T. P. Cleve, Stockholm.

2. STEPHANOCŒNIA ELEGANS, Leymerie, sp.

Leymerie described this form as a *Porites*; Michelin associated it with *Alveopora*; and Milne-Edwards and Jules Haime determined its relation with the Stylinaceæ with pali, or the *Stephanocœniæ*. The European specimens were obtained from the Eocene formations of Couiza, Coustonge, Fabresan (Aude), and of Oberburg, in Styria.

Several fractured branches of a *Stephanocœnia* unlike *Stephanocœnia intersepta*, and resembling the description of *Stephanocœnia elegans*, are in the collection of the University of Upsala, and they came from the limestone of St. Bartholomew's.

1. Astrocœnia multigranosa, Reuss.

Reuss described this form from Monte Grumi, and gave admirable figures of it in his 'Pal. Studien über die älteren Tertiärsch. der Alpen,' 1. Abtheil. There are three specimens from St. Bartholomew's which must be referred to the species. They are in the collections of the University of Upsala and of Mr. P. S. Cleve, of Stockholm.

2. Astrocœnia ramosa, Sowerby, sp., vars. 1 & 2.

There is a group of forms of *Astrocœnia* which are closely allied, namely:—the so-called species *Astrocœnia Konincki*, Edw. & H., which is *A. magnifica*, Reuss; *Astrocœnia reticulata*, Edw. & H., which is but a variety of the last; and *Astrocœnia ramosa*, the *Astræa ramosa* of Sowerby. This differs from *A. reticulata* by having slenderer branches and smaller calices. Moreover the walls are thick, and are covered with crowded granulations. *Astrocœnia tuberculata*, Reuss, I regard as a variety of *A. ramosa*. These forms are important members of the Coral-fauna of the horizon of the Cretaceous deposits of Gosau and the Corbières—of the "Craie tuffeau;" and their septal arrangement is very striking. There are eight large septa, which reach the styloid columella, and eight small and rudimentary septa.

The type is continued up into the Miocene; and *Astrocœnia ornata*, which has close affinities with all these forms, is found in the North-Italian deposits, and also in the Miocene of Antigua.

This persistence of type has been noticed by me in the case of *Astrocœnia decaphylla*, Michelin, sp., a species from the "Craie tuffeau," with six primary and four secondary septa, all of which are large and, as it were, principal. It is found in the Miocene of Jamaica (Quart. Journ. Geol. Soc. vol. xix. 1863, p. 440). Nevertheless no traces of either type had been found amongst the Eocene Coralliferous deposits. Now, however, amongst the magnificent specimens obtained by Mr. P. T. Cleve from St. Bartholomew's, there are some which must be admitted to belong to the *Astrocœnia-ramosa* series.

One group I propose to establish as variety 1, with calices not longer than $\frac{1}{10}$ inch, and with occasional grooves between them, beside the granulated walls. Another group will become variety 2. Its members have smaller calices, and much thicker branches.

The thickness of the walls between the calices, and the regularity of their disposition, characterize the species and its varieties; and the branches are of all sizes, the largest being at least $1\frac{1}{2}$ inch in thickness.

3. Astrocœnia D'Achiardii, spec. nov. Pl. XX. fig. 7.

The corallum is ramose; and the smaller branches end suddenly with rounded tips. The whole is covered with crowded irregular calices, separated by thin and sharp walls, without ornamentation. The calices are deep, often quadrangular or pentagonal; and the styloid columella is situated deeply, and is usually small.

The septa are well developed. There are eight large ones, which reach the columella, and eight smaller, which project more or less, and are of different lengths in different calices, but which do not reach the axis.

In some large calices there are 32 septa; but these are very rare. Gemmation occurs between the calices; and 16 septa exist very early.

Length of largest calices (rare) $\frac{1}{4}$ inch. Usual length $\frac{3}{20}$ inch. Branches from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch in thickness.

In the collections of Mr. P.T. Cleve and of the University of Upsala.

Loc. The limestones of St. Bartholomew's, West Indies.

Division LITHOPHYLLIACEÆ, Edw. & H.

1. ULOPHYLLIA MACROGYRA, Reuss.

Reuss has described a species which was found at Castellaro, near Castel Gomberto, under this title. Previously he had included a corresponding form within the genus *Latimœandra*; and he expresses his doubt as to the correct position of the coral by affixing a note of interrogation after the generic title of *Ulophyllia*. The absence of a columella appears to render the form rather anomalous.

After due consideration, I feel disposed to believe that the judicious palæontologist to whom we are so much indebted for such excellent work, is correct in his last determination.

A fine specimen of the species occurs in the conglomerate of St. Bartholomew's, West Indies, and is in Mr. P. T. Cleve's collection.

1. PLOCOPHYLLIA CALICULATA, Catullo, sp.

The history and diagnosis of this genus and species are admirably given by A. E. Reuss in his 'Pal. Stud. über die älteren Tertiärschichten der Alpen,' 1 Abtheil. p. 17 *.

It is found at Monte Grumi and Montecchio Maggiore.

A specimen occurs in Mr. P. T. Cleve's collection, from the conglomerate of St. Bartholomew's, West Indies.

1. MANICINA AREOLATA, Linnæus, sp.

A young specimen of this common recent West-Indian form is in Mr. Cleve's collection, and appears to have come from the conglomerate of St. Bartholomew's.

The walls are not united, although incurved considerably; but otherwise the specimen, which is fossilized like the others from the same locality, resembles the recent forms.

M. Pourtales describes the species from the Florida Reef as living in from three feet below low-water mark to five or six fathoms (Reef Corals, in No. iv. Illustr. Cat. Harvard Coll., 1871).

1. LEPTORIA PROFUNDA, spec. nov. Pl. XX. fig. 8.

The "collines" are thick; and the series of undistinguishable calices is long and deep, but wide centrally.

The septa are crowded, curved, and mostly very thick and well developed; and there are 16 in $\frac{5}{10}$ inch.

The columella is thin, but distinctly lamellar.

Greatest depth of series $1\frac{6}{10}$ inch. Breadth $\frac{9}{10}$ inch.

In the collection of Mr. P. T. Cleve, Stockholm.

Loc. In the limestone of St. Bartholomew's, West Indies.

The genus is represented in the Oberburg Eocene Coral-fauna, in

* Wiener Denkschr. vol. xxviii. p. 145.

the Lower Chalk of Gosau, Piesting and Bains de Rennes; and the recent forms are in the Pacific, Indian Ocean, and Ceylon seas.

CIRCOPHYLLIA, Edw. & Haime, Hist. Nat. des Corall. vol. ii. p. 293.

1. CIRCOPHYLLIA COMPRESSA, spec. nov. Pl. XX. fig. 9.

The corallum is tall, subturbinate, curved in the plane of the greatest axis of breadth, and is compressed laterally from the small peduncle to the deep calice.

The calice is elliptical in shape; its margin is stout; the fossa is deep, and the longer septa reach a well-developed columella with a flat top.

The septa are of different and unequal sizes. There are five cycles of them in six systems; but the members of the fifth cycle are very small, and do not reach far from the margin. The primary and secondary septa are equal; and the tertiaries are nearly as large; but all are rather small. There are 48 septa that reach the columella.

The costæ are distinct, and are alternately large and small; all are delicate, straight, and slightly prominent. Those of the fifth cycle are very distinct.

The exotheca is well developed; and there are annular traces of a rudimentary epitheca.

Height of type $1\frac{3}{10}$ inch. Breadth of calice $\frac{9}{10}$ inch.

Loc. St. Bartholomew's, West Indies.

Collection of Mr. P. T. Cleve, Stockholm.

2. CIRCOPHYLLIA CLEVEI, spec. nov. Pl. XXI. fig. 10.

The corallum is turbinate, slightly or decidedly compressed superiorly, and has a small mamilliform peduncle.

The calice is elliptical, open, moderately deep; and its margins are rarely incurved.

The septa are in six systems; and there are five cycles of them. The septa of the highest cycles are small; and those of the other cycles are large, long, and reach the columella, which is distinct and flat.

The wall is thick. The costæ are subequal superiorly, and are wide apart everywhere.

The exotheca is slightly developed.

Height of corallum $1\frac{1}{2}$ inch. Breadth of calice 2 inches. This relative length and breadth of 3 to 4 is very general in specimens.

Loc. St. Bartholomew's, West Indies.

Collections of the University of Upsala and of Mr. P. T. Cleve, of Stockholm.

Most of the specimens, which are numerous, have been rolled; some are broken; and others are partly imbedded in volcanic débris. All indicate, however, that they had a vigorous nutrition; for they are large forms, and possess numerous septa.

Reuss, in his admirable description of the Anthozoa of Castel Gomberto*, notices a form which has all the characters of the genus *Cyathophyllia*, Fromentel & Ferry, except that he pronounces the epitheca to have been worn off.

Now this genus was established by the careful palæontologists whose names it bears to include one species from the Lias; but a year

* *Op. cit.* vol. xxviii. 1868, p. 170.

before the volume of the 'Paléontologie Française' appeared which contains their diagnosis of the new genus, I had established the equivalent genus *Antillia*, which therefore must have the precedence *. Lonsdale, in a MS. in my possession, proves that he had studied the *Antilliæ*; but he regarded them as *Circophylliæ*. The stout epitheca, which is so persistent in *Antillia*, separates it as a genus from *Circophyllia*, which has none, or only a trace. There is, of course, a possibility that the epitheca may be worn off during rolling; but it could not be so affected without damaging the costæ. If, therefore, the costæ remain prominent, with a small rudimentary epitheca, it is advisable to class the form possessing these attributes amongst the *Circophylliæ*, Edw. & H. Hence I consider that, as Reuss has sagaciously hinted, *Cyathophyllia annulata*, Reuss, from Monte Viale (Oligocene), should be termed *Circophyllia annulata*, Reuss, sp.

Division Faviaceæ, Edw. & H.

1. Goniastræa variabilis, spec. nov. Pl. XXI. fig. 11.

The corallum is massive, ovoid and depressed in shape; and the corallites radiate from a small base.

The upper surface is slightly convex, and is crowded with calices of different sizes, and all more or less angular in outline.

The walls are thin, united, and slightly wavy.

The fossæ are shallow; and the columellæ differ greatly in their development. Usually they are spongy and well developed; sometimes they are distinctly linear, and formed by one lamella; and in some young corallites the columella barely exists.

The septa are alternately thick and very slender; they are short and wide apart; they are few in number, and are without distinct cyclical order.

There are some calices with 12, and others with septa reaching to 40 in number, and many intermediate sizes.

Fissiparity is frequently observed.

Height of the corallum $1\frac{3}{10}$ inch. Length 3 inches. Breadth $2\frac{1}{4}$ inches. The long axis of calices from $\frac{2}{10}$ to $\frac{3}{10}$ inch.

Loc. The conglomerate of St. Bartholomew's.

In the collection of Mr. P. T. Cleve, Stockholm.

The nearest species with which this can be associated is *Goniastræa solida*, Edw. & H., which is found in the recent fauna of the Red Sea and the Seychelles, and which forms part of the raised reefs of the Arabian shore of the Red Sea.

The lamellar condition of the columella in some corallites is very interesting, and foreshadows the genus *Lamellastræa* (Duncan, Foss. Corals West Indies, part iv. p. 20, Quart. Journ. Geol. Soc. vol. xxiv. 1868).

Division Astræaceæ, Edw. & H.

1. Solenastræa columnaris, Reuss.

This species was found by Catullo at Montecchio Maggiore, and was described by Reuss from Monte delle Carrioli, near Polesella, in the Castel-Gomberto district.

* Quart. Journ. Geol. Soc. vol. xx. p. 28, Feb. 1864.

It is represented by several specimens from St. Bartholomew's, in the West Indies, in Mr. P. T. Cleve's collection.

Family FUNGIDÆ.

Subfamily Lophoserinæ, Edw. & Haime.

Genus Turbinoseris, Duncan, Palæontological Society's Memoirs, vol. xxiii.; Cretaceous Corals, pt. ii. p. 42.

The characters originally given for this genus are as follows:—

The corallum is simple, more or less turbinate, or constricted midway between the base and calice. The base is either broad and adherent, or small and free.

There is no epitheca; and the costæ are distinct. There is no columella; and the septa, which are very numerous, unite laterally.

The genus is allied to *Trochoseris*, Edw. & H.; but this group has a columella, a structure which is not found in *Turbinoseris*.

The only species hitherto described is from the Atherfield Clay of the Lower Green Sand; but the genus is well represented in the St.-Bartholomew's deposits by species, varieties, and many individuals.

I now amend the generic diagnosis as follows:—

Turbinoseris, Duncan.

The corallum is simple and turbinate, or conical. The base is either broad, with a mark of former adherence, or narrow and free. The epitheca is rudimentary, but frequently is distinct. Synapticulæ usually present between the costæ and septa also. Septa and costæ numerous.

The genus may be subdivided into two groups:—with species which have the costæ close together and united by numerous synapticulæ; and a second, the species of which have no synapticulæ between the costæ, which are wide apart.

1. Turbinoseris eocænica, spec. nov. Pl. XXI. fig. 12.

The corallum is tall and greatly compressed. At the base there is a sharp peduncle, from which the sides pass rather abruptly outwards and upwards at first, and then they diverge but slightly to the calice. The shape is that of a narrow and compressed cone.

The calice is elliptical in outline; and its margins are either horizontal or slightly arched in the direction of its long axis. It is shallow; and there is no columella. In its long axis there is a linear space, which is bounded by the enlarged ends of the larger septa.

The septa are very numerous, crowded, unequal; and the smaller frequently join the larger by their sides.

There are five complete cycles of septa in six systems; and there are a few laminæ of the sixth cycle. The larger septa reach and form the horizontal floor of the calice; and their ends are swollen, and bound the axial space. Numerous and delicate synapticulæ join the septa.

The costæ are delicate, subequal, very numerous, close, wavy occasionally, and are connected by numerous well-developed synapticulæ, which are placed very closely.

The costal and septal numbers were attained very early in the life of the coral.

The epitheca is rudimentary, and barely exists.

The wall is thick.

Inferiorly, the tissues around the peduncle are usually worn off.

Height of full-grown specimen, 1 inch. Length of calice $\frac{7}{10}$ inch. Breadth $\frac{4}{10}-\frac{5}{10}$ inch.

Loc. Limestone of St. Bartholomew's, West Indies.

In the collections of the University of Upsala and of Mr. P. T. Cleve, Stockholm.

The immature specimens of this species resemble the lower half of the full-grown, and are compressed and wedge-shaped.

2. Turbinoseris major, spec. nov. Pl. XXI. fig. 13.

The corallum is pedunculate, tall, narrow, conical, and compressed.

The calice is elliptical in outline and deep.

The septa are slightly exsert, crowded, alternately large and small, and they pass down deeply into the fossa.

Their laminæ diminish in size from the margin inwards.

There are five cycles of septa in six systems.

The synapticulæ are scanty.

The costæ are delicate, close, subequal, and the larger are flat and faintly granular. All are connected by numerous horizontal and sometimes oblique synapticulæ.

The wall is very thick. Epitheca quite rudimentary.

Height $1\frac{3}{10}$ inch. Length of calice $\frac{9}{10}$ inch. Breadth $\frac{6}{10}$ inch.

Loc. Limestone of St. Bartholomew's.

In the collection of the University of Upsala.

3. Turbinoseris grandis, spec. nov. Pl. XXII. fig. 14.

The corallum is short, very broad, and compressed, and has a sharp peduncle.

The calice is elliptical in outline; and its margin is not quite horizontal, but is thick.

The fossa is shallow.

The septa are numerous, crowded, alternately large and small, and the larger end internally with swollen terminations along an axial space. There are five cycles, and a few septa of the sixth, in six systems. All are joined by numerous synapticulæ; and the smaller septa join the larger occasionally.

The costæ are subequal, broad, close, and swollen at the junction of the numerous synapticulæ.

The epitheca exists in some specimens.

Usually the wall is much worn around the peduncle.

Height of corallum $\frac{9}{10}$ inch. Length of calice $1\frac{1}{10}$ inch. Breadth $\frac{7}{10}$ inch.

Loc. In the limestone and conglomerate of St. Bartholomew's.

In the collections of the University of Upsala and of Mr. P.T. Cleve.

4. Turbinoseris angulata, spec. nov. Pl. XXII. fig. 15.

The corallum is short, turbinate, compressed, and finely pedunculate.

The calice is widely open, very shallow and elliptical in outline; and the margins are somewhat angular, especially at the long axis.

The septa are excessively thin and long, and correspond to larger costæ. There are five cycles, and some of the sixth, in six systems.

The costæ are close, unequal, transversely granular, and those at the end of the long axis of the calice are the most prominent and broadest. Inferiorly synapticulæ exist. Epitheca rudimentary.

Height of corallum $\frac{5}{10}$ inch. Length of calice $1\frac{3}{10}$ inch. Breadth $\frac{9}{10}$ inch.

Loc. Limestone of St. Bartholomew's, West Indies.

In the collection of Mr. P. T. Cleve, Stockholm.

5. Turbinoseris antillarum, spec. nov. Pl. XXII. fig. 16.

The corallum is turbinate and compressed. It has a sharp peduncle.

The calice is elliptical in outline, very shallow and open.

The septa are numerous, long, thin, and curved. The shorter join the longer not far from the centre; and these pass inwards thus increased in size.

The costæ are equal, longer than the septa, and smaller inferiorly than at the calicular margin.

The synapticulæ are not abundant. The epitheca is banded.

Height of corallum $1\frac{3}{10}$ inch. Length of calice 1 inch. Breadth $\frac{8}{10}$ inch.

Loc. Limestone of St. Bartholomew's, West Indies.

In the collection of Mr. P. T. Cleve, Stockholm.

6. Turbinoseris Clevei, spec. nov. Pl. XXII. fig. 17.

The corallum is turbinate and compressed. It has a broad peduncle, with the mark of a former attachment.

The calice (section) is elliptical.

The septa are numerous, very irregular in their course, thin, and unequal.

The costæ are prominent, unequal, and distant, the wall being visible between them.

The synapticulæ are large between the septa, but do not exist between the costæ. The wall is thick. There is no epitheca.

Height of corallum $\frac{9}{10}$ inch. Length of calice $\frac{9}{10}$ inch. Breadth $\frac{6}{10}$ inch.

Loc. Limestone of St. Bartholomew's, West Indies.

In the collection of Mr. P. T. Cleve, Stockholm.

7. Turbinoseris cyclolites, spec. nov. Pl. XXII. fig. 18.

The corallum is very short, has a widely open calice, a small mamilliform peduncle, and an almost horizontal wall.

The calice is elliptical, and has a central fossa.

The septa are small and crowded.

The costæ are distinct, mamilliform here and there; and some are larger than the others.

Height of corallum $\frac{3}{10}$ inch. Breadth of calice $\frac{8}{10}$ inch.

Loc. Limestone of St. Bartholomew's, West Indies.

In the collection of Mr. P. T. Cleve, Stockholm.

The resemblance of this form to one of the genus *Palæocyclus* is most remarkable. There are no tabulæ, however; and I have

already shown that this Palæozoic group of forms should be classified under the *Cyathophyllidæ*.

MADREPORARIA PERFORATA, Edw. & H.

Family MADREPORIDÆ.

Subfamily TURBINARINÆ.

1. ASTRÆOPORA PANICEA, Pictet.

This species is found in the Eocene deposits at Valmondois; and a rolled specimen came from the conglomerate of St. Bartholomew's, West Indies.

In the collection of the University of Upsala.

1. ACTINACIS ROLLEI, Reuss.

Reuss has described this species from Oberburg in Styria (Denkschriften der kaiserl. Akad. der Wissenschaft. Wien, 1864).

A large specimen is from the limestone of St. Bartholomew's, and belongs to Mr. P. T. Cleve, of Stockholm.

Family PORITIDÆ.

1. PORITES RAMOSA, Catullo.

Reuss has noticed this species at Crosara and in the Castel-Gomberto district; and it is characteristic of the Upper Eocene of Monte Titano (A. Manzoni), where small nummulites exist. It forms banks in that locality.

A specimen is in Mr. P. T. Cleve's collection, and came from the conglomerate of St. Bartholomew's, West Indies.

List of the Species of Fossil Corals found in the Limestone and Conglomerate of St. Bartholomew's, West Indies.

Flabellum appendiculatum, *Brongniart*, sp.*
Trochosmilia subcurvata, *Reuss.*†
—— insignis, sp. nov.
—— arguta, *Reuss.*‡
Asterosmilia Pourtalesi, sp. nov.
Circophyllia compressa, sp. nov.
—— Clevei, sp. nov.
Stylophora compressa, sp. nov.
—— distans, *Leymerie*, sp.‡
—— conferta, *Reuss.*‡
—— tuberosa, *Reuss.*‡
—— granulata, *Duncan.**
—— affinis, *Duncan.**
Stylocœnia emarciata, *Lamarck*, sp.§
Stephanocœnia incrustans, sp. nov.
—— elegans, *Leymerie*, sp.†
Astrocœnia multigranosa, *Reuss.*‡
Astrocœnia ramosa, *Sowerby*, sp.‖
—— d'Archiardii, sp. nov.
Ulophyllia macrogyra, *Reuss.*‡
Plocophyllia caliculata, *Catullo*, sp.‡
Manicina areolata, *Linnæus*, sp.¶
Leptoria profunda, sp. nov.
Goniastræa variabilis, sp. nov.
Solenastræa columnaris, *Reuss.*‡
Astræopora panicea, *Pictet.***
Actinacis Rollei, *Reuss.*†
Porites ramosa, *Catullo.*‡
Turbinoseris eocænica, sp. nov.
—— major, sp. nov.
—— grandis, sp. nov.
—— angulata, sp. nov.
—— antillarum, sp. nov.
—— Clevei, sp. n.
—— cyclolites, sp. n.

* European localities, Biarritz and Ronca: Eocene. Found also in the Miocene deposits of the West Indies. † European locality, Oberburg: Eocene.
‡ European localities, Castel Gomberto, Monte Grumi, Montecchio Maggiore: Oligocene. § Common in the Eocene of Europe and Asia.
‖ Found in the Cretaceous strata of Gosau &c.
¶ Recent Caribbean. ** Eocene of Valmondois.

Of these thirty-five species only one belongs also to the recent Coral-fauna; fifteen species are common to European Eocene and Lower Oligocene deposits; two are also Miocene forms; one is a Cretaceous species; and sixteen are new to science.

The affinities of the new species are as follows:—

Trochosmilia insignis	with the European Eocene *Trochosmiliæ*.
Asterosmilia Pourtalesi	with the San-Domingan Miocene species.
Circophyllia compressa —— Clevei	with the European Eocene and Lower Oligocene species.
Stylophora compressa	with the European Oligocene and Miocene, and West-Indian Miocene species.
Stephanocœnia incrustans	with the European Oligocene species.
Astrocœnia d'Achiardii	with the European Cretaceous species.
Leptoria profunda	with the European Cretaceous and Eocene, Pacific recent species.
Goniastræa variabilis	with the Red-Sea and Pacific recent species.
Turbinoseris, seven species.	The genus hitherto has been known only in the Lower Greensand.

The following is the geological range of the genera:—

Flabellum	from the Eocene to the recent period inclusive.
Trochosmilia	from the Gault to the Miocene period inclusive *.
Asterosmilia	from the Eocene to the Miocene period inclusive †.
Circophyllia	from the Eocene to the Lower Oligocene inclusive.
Stylophora	from the Coral-rag to the recent period inclusive*.
Styloccœnia	from the Eocene to the Miocene period inclusive.
Stephanocœnia	from the Coral-rag to the recent period inclusive*.
Astrocœnia	from the Infra-Lias to the recent period ‡.
Ulophyllia	from the Coral-rag to the recent period inclusive §.
Plocophyllia	from the Eocene to the Lower Oligocene.
Manicina	from the Eocene to the recent period ‡.
Leptoria	from the Coral-rag to the recent period §.
Goniastræa	from the Lower Cretaceous to the recent period §.
Solenastræa	from the Eocene to the recent period ‖.
Astræopora	from the Eocene to the recent period §.
Actinacis	from the Lower Cretaceous to the Lower Oligocene.
Porites	from the Lower Cretaceous to the recent period ‖.
Turbinoseris	from the Lower Greensand to the Eocene period.

Remarks on the Species, and their distribution.

Thus, out of eighteen genera, six are extinct; and of the remaining twelve, five are common to the Caribbean and Pacific and East-Indian Coral-faunas. Of the seven still unaccounted for, five are members of the Coral fauna to the west of the continent of America, and two of the Caribbean fauna.

Only one species, *Manicina areolata*, is still existing in the Caribbean Coral-fauna; and all the others are extinct.

The reef-building corals amongst the thirty-five species were the *Stylophoræ*, the *Stylocœnia*, the *Stephanocœniæ*, the *Astrocœniæ*, the *Ulophyllia*, *Plocophyllia*, *Leptoria*, *Goniastræa*, *Solenastræa*, *Astræopora*, *Actinacis*, and *Porites*.

* Common to the Pacific and West-Indian Coral-faunas.

† Probably Count Pourtales has met with a species in the West Indies.

‡ In the West-Indian Coral-fauna.

§ In the Pacific and East-Indian Coral-faunas.

‖ Common to the Pacific and West-Indian Coral-faunas.

The species of the genera *Flabellum*, *Trochosmilia*, *Asterosmilia*, *Circophyllia*, *Turbinoseris*, and *Manicina* probably lived in the lagoon, or in deep water outside the reef.

It is evident that during the period which intervened between the deposition of the Hippuritic Cretaceous strata and those of the Miocene, in the West Indies, there were coral reefs flourishing in the N.E. Caribbean, and that the area was one of volcanic activity. The cretaceous deposits of Jamaica, and those of St. Thomas and St. Croix, are probably of the same age, and should be assigned to the same horizon as the Upper Greensand, the "Craie tuffeau," and the Gosau Chalk; and from the nature of the corals described by Reuss in Europe, and myself from the West-Indian strata, it may be decided that they were collected together in and about coral reefs. No White Chalk is known in the West-Indian area as yet; and probably it never accumulated there; but the Jamaican and the other cretaceous reefs continued to flourish during the deposition of the oceanic sediment to the east, and were not finally overlapped by it, as were the European reefs, and also the deposits far away to the north in North America.

Although there are clear proofs of there having been great alterations in the cretaceous reefs and their accumulated deposits in Jamaica before the deposition of any other sediments, still there are no evidences of volcanic activity there. But in the Virgin Islands volcanic ejectamenta are mingled with the cretaceous remains; and the geology of the district, so ably stated by Mr. Cleve*, proves that a series of volcanic eruptions terminated the Cretaceous period, and that reefs were upheaved and the habitat of the reef-builders was destroyed.

The volcanic activity was probably a part of the phenomena incident to the great crust-movement which witnessed the upheaval of the abyssal deposits of White Chalk. And if this were the case, the equivalency of the coralliferous deposits on either side of the Atlantic was as follows:—

First. During the age of the Upper Greensand and Chalk Marl, there were reefs in the Caribbean, in Austria, S. France, &c.

Secondly. The overlap of the White Chalk overwhelmed the European reefs during a long period of subsidence; but the West-Indian reefs were in a volcanic region, and therefore on the edge of areas of unstable equilibrium. They were not on an area of subsidence, and they lasted on.

Thirdly. The upheaval of the abyssal deposits was accompanied by great volcanic disturbances in the Caribbean; and the Coral-fauna of the Upper White Chalk of Europe and that of the Jamaican and Virgin-Islands area represented the degenerating coral-life of the period. They differed in species; for the one was younger than the other.

The Eocene reefs collected around the volcanoes and the upheaved Hippurite-chalk in the Caribbean; and the examination of their remains proves:—1, that the species may be associated with five Coral-

* *Op. cit.*

faunas, viz. the Cretaceous, the Eocene, the Lower Oligocene, the Miocene, and the existing Coral-fauna; and, 2nd, that the duration of the reefs was vast; for in Europe the Eocene reefs are very thick, and are separated by a deep flysch from the great coralliferous Oligocene deposits.

The longer a reef lasts the less probable is the preservation of its earliest components, and age after age produces slight but, in the long run, important variations in the general composition and nature of the fauna; so that it is impossible to obtain the forms which link a reef to its predecessor. Only the latest forms are preserved, or those which were flourishing when the changes commenced which determined the destruction of the reef. The ordinary wear and tear, the very nature of the superpositing reef-builders, and the metamorphosis of coral limestone are opposed to the perpetuation of very old specimens.

Hence, when the Eocene deposits of St. Bartholomew's are examined, only the last page of the history is read; and were it not for the persistence of some types, the nature of their early times would be a closed book.

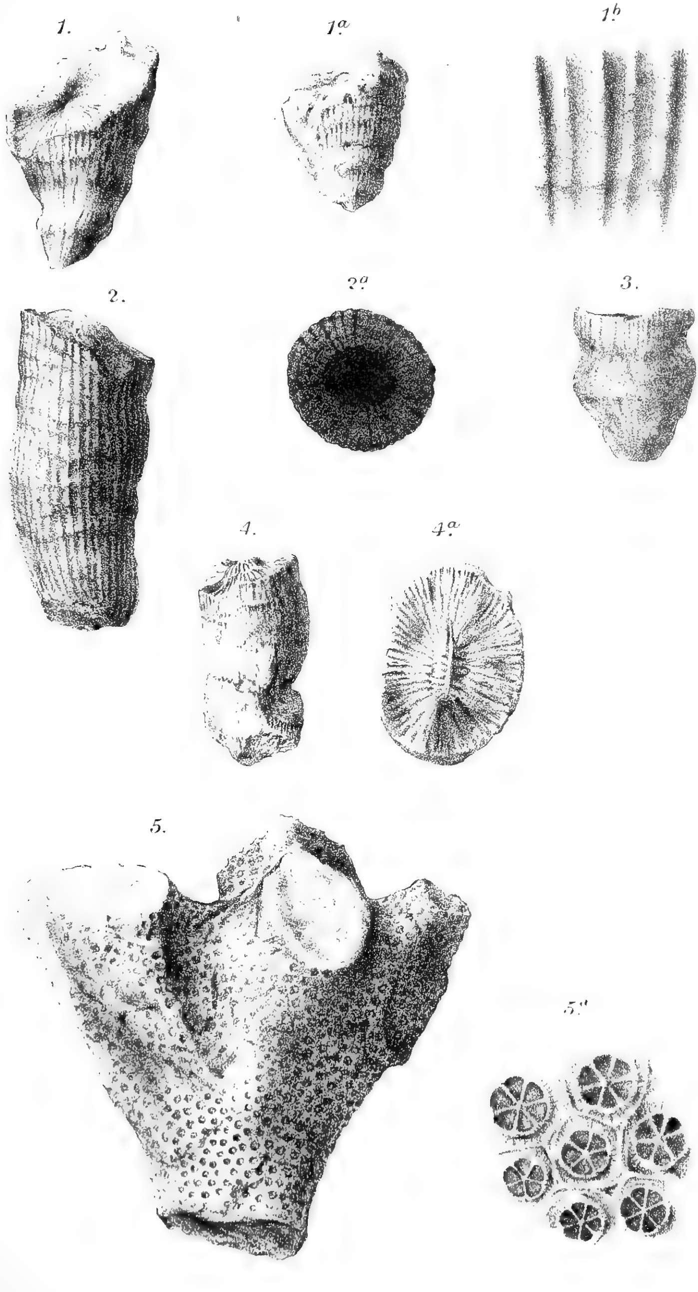
They included at the last a species (*Astrocœnia ramosa*) and varieties which are eminently characteristic of the Gosau area; and as the Hippurite-chalk of Jamaica has been proved to contain similar species to those which then flourished in the Gosau chalk, so it is reasonable to infer that these lingering forms were the descendants of the Coral-fauna which preceded the Eocene in the Caribbean area.

I believe that the other species of *Astrocœnia* are the result of the modification in their secondary characters of the above-mentioned *Astrocœnia ramosa*—a very variable form. Now the St.-Bartholomew *Stephanocœniæ* belong to a Cretaceous group with eight septa; and the costæ of the *Trochosmiliæ* are eminently suggestive of some forms described by Reuss from Gosau.

The genera *Leptoria*, *Goniastræa*, and *Actinacis* were well represented in the European "Craie tuffeau;" and as there was a community of species at the time of the deposition of its sediments and those of the Cretaceous of the Northern Caribbean, it is reasonable to assert that the Eocene species were the modified descendants of those which flourished in the preceding cretaceous reefs.

The St.-Bartholomew deposits contain species which in Europe belong to two Lower Tertiary horizons, the Nummulitic and the Lower Oligocene; and it would appear that a great subsidence determined in Europe the formation of the Flysch which is intercalated between the two deposits. No such sediment is found in the West Indies; and it is therefore highly probable that the Oligocene reefs of the Castel-Gomberto district were supplied with certain species which could last there from the West-Indian and Atlantic reefs. This change of habitat naturally produced variation; and the magnificent Coral-fauna of the Vicentin and its neighbourhood resulted.

It is an interesting fact that Cretaceous, Eocene, Miocene, Pliocene, and recent reefs should have followed each other in the same area, and that volcanic action should have been more or less intense there during these long periods.



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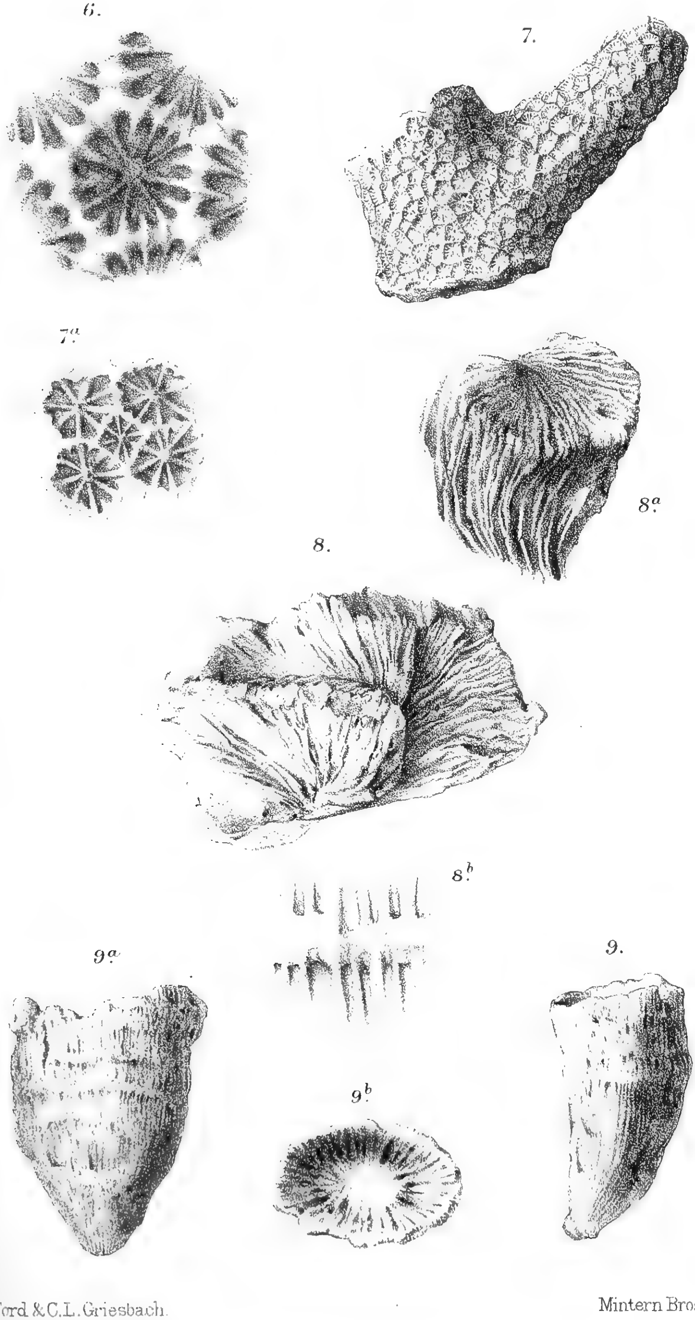

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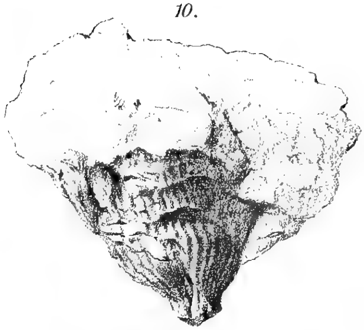

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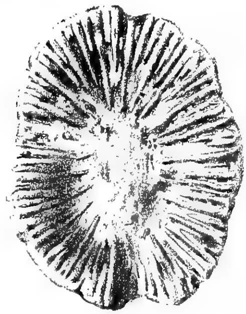

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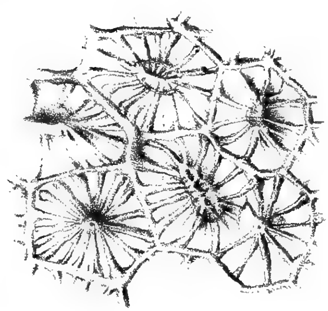

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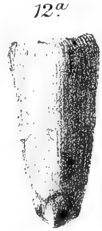

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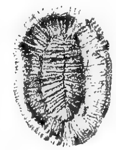

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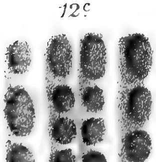

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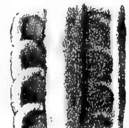

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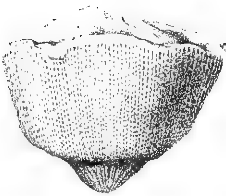

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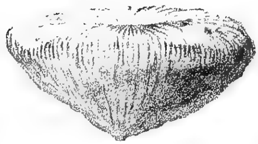

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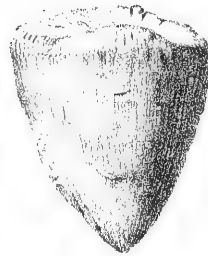

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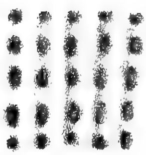

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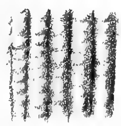

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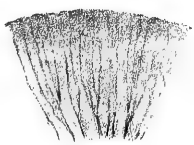

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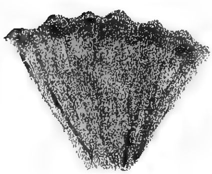

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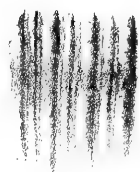

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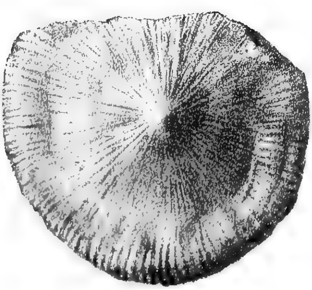

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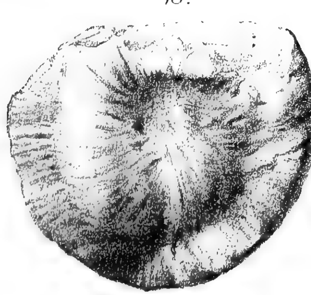

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EXPLANATION OF PLATES XIX–XXII.

Plate XIX.

Fig. 1. *Trochosmilia subcurvata*, Reuss. 1 *a*. Ditto, var. 1 *b*. Costæ, magnified.
2. —— *insignis*. 2 *a*. Section.
3. —— *arguta*, Reuss.

Fig. 4. *Asterosmilia Pourtalesi*, spec. nov. 4 *a*. Calice, magnified.
5. *Stylophora compressa*, spec. nov. 5 *a*. Calices, magnified.

Plate XX.

Fig. 6. *Stephanocœnia incrustans*, sp. nov. Calices, magnified.
7. —— *d'Achiardii*, sp. nov. 7 *d*. Calices, magnified.
8. *Leptoria profunda*, spec. nov. 8 *a*. End of a calice, slightly enlarged. 8 *b*. Columella and septa, magnified.

Fig. 9. *Circophyllia compressa*, spec. nov., side view. 9 *a*. Ditto, front view. 9 *b*. The calice.

Plate XXI.

Fig. 10. *Circophyllia Clevei*, spec. nov. 10 *a*. Calice. 10 *b*. Exotheca, magnified.
11. *Goniastræa variabilis*, sp. nov. Calices, magnified.
12. *Turbinoseris eocænica*, spec. nov. 12 *a*. Side view. 12 *b*. Calice. 12 *c*. Costal synapticulæ, magnified.

Fig. 13. *Turbinoseris major*, spec. nov. 13 *a*. Synapticulæ and costæ, magnified.

Plate XXII.

Fig. 14. *Turbinoseris grandis*, spec. nov. 14 *a*. Costal synapticulæ, magnified.
15. —— *angulata*, spec. nov. 15 *a*. Costæ magnified.
16. —— *antillarum*, spec. nov. 16 *a*. Part of section of calice, magnified.

Fig. 17. *Turbinoseris Clevei*, spec. nov. 17 *a*. Section of calicular end, magnified. 17 *b*. Costæ, magnified.
18. —— *cyclolites*, sp. nov. 18 *a*. Base, magnified. 18 *b*. Calice, magnified.

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7. *Note on the* Lignite Deposit *of* Lal-Lal, Victoria, Australia. By R. Etheridge, Esq., junior, F.G.S. (of the late Geological Survey of Victoria).

The observations recorded in the present note were made at the latter end of the year 1868, during a preliminary survey of the Mount Buninyong District, Victoria. Unfortunately, through the dissolution of the late Geological Survey by the Colonial Government, circumstances did not permit of my carrying them to a successful termination.

The village of Lal-Lal is situated about 3 miles to the south of Mount Buninyong, in the Buninyong District, Victoria. The surface aspect of the ground occupied by the lignite deposit is, in winter, that of a sandy marshy flat, in summer dry and parched, covered with coarse grass, and of no great extent. The country immediately to the north of Lal-Lal is composed of granitic rocks overlain by the lava-flows of Mounts Buninyong and Warrenheip, which extend some distance to the northward. On the south and west the

deposit is bounded by the low Silurian hills of Williamson's Creek, and the Mount-Doran ranges. The Melbourne, Geelong, and Ballarat Railway crosses the western edge of the Lal-Lal flat; and near this a shaft was sunk by the "Lal-Lal Lignite Company," which appears to have struck the bed about its thickest point, viz. 115 feet, as later mining operations have proved that it thins out all round this point. The supposition would therefore be that the position of the shaft represents nearly the centre of the bed of lignite. The following is a generalized section from above downwards:—

1. Alternations of sand, clay, and gravel, about 73 feet.
2. Fine fire-clay, about 3 feet.
3. Lignite, about 115 feet.

At several other points round the main sinking the bed of lignite was struck at a less depth; but, so far as I observed, no outcrop was to be seen.

The lignite consists of an irregular mixture of brown or brownish-black earthy bituminous coal, *i.e.* a mixture of both brown coal and lignite, composed of branches, roots, and other remains of coniferous trees. Throughout the whole mass a few shattered thin seams of jet and a few clay beds are met with, accompanied by two kinds of resin. One of the latter, "semitransparent, of a honey-yellow or reddish-brown colour, and very brittle, resembles *Middletonite*: the other is greyish-white, opaque, earthy, and somewhat flexible and elastic when fresh from the mine, but becomes hard and brittle afterwards; it most nearly resembles *Retinite* from the Bovey Coal. Both these resins burn easily, and, emitting with much smoke fine fragrant odours, leave shining carbonaceous residues" (Selwyn & Ulrich, Phys. Geog. & Geol. Vict. pp. 80 & 81).

Several analyses of Lal-Lal lignite were made at various times in the laboratory of the Geological Survey by the late Mr. Charles Wood and by my former colleague, Mr. Cosmo Newbery, of which the following are a sample:—

	I.	II.	III.
Fixed carbon	29·3	26·7	39·0
Volatile matter	20·7	23·3	20·4
Hygroscopic water	48·7	48·7	40·0
Ash	1·3	1·3	0·6
	100·0	100·0	100·0

The above analyses show, from the small percentage of ash, that this lignite might be used with advantage for steam-purposes, although the amount of carbon falls short of the general quantity of that element found in most lignites, more especially those of Germany, many of which contain as much as from 50 to 70 per cent.; one, that from Ellbogen in Bohemia, is recorded by Regnault as containing 73 per cent. of carbon. Unfortunately the Lal-Lal lignite has hitherto been found to burn away too quickly for commercial purposes; this is to be regretted, since the deposit lies within easy reach of the most important of the Victorian gold-fields, Ballarat.

During 1871 the Lal-Lal Brown Coal Company raised 995 tons of brown coal, only half of which, however, was saleable. (R. B. Smyth, Mining and Mineral Statistics.)

From the desultory and unsatisfactory manner in which the age of the various Tertiary beds of Victoria has been arrived at, it is difficult to fix in an exact manner that of the Lal-Lal beds. The flora, so far as it has been investigated, appears to be of a Gymnospermous character. Victoria at that time must have presented a much more tropical appearance than it does now. So far as I am aware, none of the Victorian indigenous trees has been noticed in this brown coal, which appears to be almost entirely composed of the remains of *Coniferæ*. We can therefore arrive at its age by analogy only.

The series of beds classed as Miocene by Mr. Selwyn, and so well developed in the Maud district, are divided by my former colleague (Mr. C. Wilkinson, who devoted much time to their investigation) into two parts—an upper or marine series, and a lower, and apparently freshwater series. The first or marine series contains, according to Prof. M'Coy, a fauna of true Miocene age, and littoral in character. The latter or supposed freshwater series is composed, as Mr. Wilkinson has informed me, of sands, sandy clays, pipe-clay, and rounded quartz and sandstone gravel, with thick masses of a hard siliceous rock, or quartzite, interstratified with the foregoing without any order or position. This siliceous rock, full of plants, is traceable at intervals from Maud to Meredith, thence to Morrison's Diggings on the Tea-Tree Creek, where it occurs accompanied by a large amount of vegetable matter and thin irregular bands of lignite, and forms the "false bottom" on which the younger auriferous drifts are worked. At Morrison's Diggings a prospecting shaft was sunk into this deposit to a depth of 400 feet, passing through gravels and clays, containing numerous trees and plants. The following sections taken near the above localities will give a fair illustration of the foregoing remarks :—

Section near Golden Rivers.

1. Upper basalt rock, 25 to 30 feet.
2. Gravel (Pliocene ?), 50 to 60 feet.
3. Gravel (Miocene ?), "false bottom of miners," gravel, sand, clay, and boulders, with fossil leaves and wood, about 400 feet.
4. Silurian (bed-rock).

Section on the Moorabool River, west of Steiglitz.

1. Upper basalt, 49 feet.
2. Sandy grit (Pliocene ?), 10 to 15 feet.
3. Upper coralline limestone, 13 feet.
4. Older basalt, enclosing bands of hard compact limestone, with fossils.
5. Sandy limestones, with fossils.
6. Rounded quartz, pebble drift, and hard siliceous conglomerate rock, with fossil wood, &c., 90 feet.

Miocene.

7. Silurian (bed-rock).

(Selwyn & Ulrich, *l. c.* p. 22.)

This peculiar and characteristic conglomerate was traced by Mr. Wilkinson and his party as far north as Bacchus Marsh, maintaining

its peculiar lithological character throughout. The plants there obtained by Mr. Wilkinson were pronounced by Prof. M'Coy to be allied to the Lower Miocene or Upper Eocene European flora; in fact a few genera and one or two species are identical—for instance, *Cinnamomum polymorphum*, a plant, according to Heer, common in the Miocene beds of Œningen.

I have previously stated that the conglomerate siliceous rock was traced to Meredith. From this point my former colleague, Mr. Reginald Murray, and myself traced it to the village of Stony Rises, within about $2\frac{1}{2}$ miles of the Lal-Lal basin; but there we lost all traces of it. That it was connected with the Lal-Lal lignite in a similar manner to that of Morrison's Diggings we did not prove; but the facts I have enumerated tend to that belief; and whatever may be the relative value attached to the terms *Miocene* and *Pliocene* as applied to Victorian geology, I think it will ultimately be proved that the two lignite deposits of Morrison's Diggings and Lal-Lal are closely connected as regards their age and mode of formation.

Mr. Wilkinson was of opinion that the Maud beds represented a lacustrine deposit with one of its margins formed by the Steiglitz ranges. An old valley, 300 to 400 feet deep, was traced from these hills down to the Moorabool river, and there appears to have entered this old lake. The physical geology of the surrounding districts supports the idea that this was a lake with many rivers flowing into it.

With regard to the plants from the Bacchus-Marsh beds, Prof. M'Coy says: "I have no doubt the fossil leaves from this locality indicate a lower Miocene or Upper Eocene Tertiary flora, in which lauraceous plants form a remarkable feature. All the species seem new; but leaves of *Laurus, Cinnamomum, Daphnogene,* and possibly *Acer,* are scarcely to be distinguished from species referred to those genera in the leaf-beds of Rott, near Bonn, and Œningen, especially the *Cinnamomum polymorphum.*" (R. B. Smyth, Ex. Essay, 1872, p. 15, note.)

Lignite has been plentifully found in the auriferous "leads" of Ballarat, Daylesford, and other localities, principally formed of the remains of trees and plants belonging to genera which form a portion of the existing flora, as *Banksia, Eucalyptus,* &c., indicating a younger age than the Lal-Lal lignite. Fruits of a new genus of Coniferæ, *Spondylostrobus,* Von Müller (*S. Smythii,* Von Müller), together with other plants, have also been obtained from the Haddon Leads near Smythesdale (Quart. Journ. Geol. Soc. vol. xxvi. p. 610)*.

A survey of the Ballarat district is, I believe, at present in course of completion by Mr. Murray. This will, I have no doubt, confirm or correct, as the case may be, some of the views here expressed.

* Dr. von Müller has since considerably increased the number of both genera and species of plants from the Haddon Leads. The remains are principally fruits. See the 'Reports of the Mining Surveyors and Registrars,' Victoria, 1871.

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

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1. NOTE *on* ZOOPHYCUS GIGANTEUS. By M. K. KALKBRENNER.

[Proc. Imp. Geol. Inst. Vienna, July 31, 1873.]

SOME peculiar structures discovered in the Carpathian sandstone, near the Wallensdorf Station (Hungary), are regarded by the author as traces of Algæ, and described by him under the name of *Zoophycus giganteus.* They are large semicircular impressions, with concentric furrows and a broad folded or lobate border. It is remarkable that these impressions do not lie parallel to the bedding, but always stand perpendicular to it in the rock. The size of the impressions varies between 3 and 5 feet. [W. S. D.]

2. *A new* CEPHALOPOD, *from the horizon of* CERATITES REITZI, *in the district of* BAKONY. By M. J. BOECKH.

[Proc. Imp. Geol. Inst. Vienna, July 31, 1873.]

THE author describes a new Ammonite from the limestone with *Ceratites Reitzi* of Felsö-Örs, in the valley of Király-kut-er (Hungary). In external form it presents a close resemblance to *Ammonites floridus*; but its septal markings remind one of those of *Goniatites Orbignyanus* and *Ceratites Haidingeri.* The author names it *Ammonites* (*Sageceras*) *Zsigmondyi.* [W. S. D.]

3. MONTE TITANO, *its* FOSSILS, STATE, *and* MODE *of* ORIGIN. By M. A. MANZONI.

[Boll. del R. Comit. Geol. 1873, and Proc. Imp. Geol. Inst. Vienna, July 31, 1873.]

MONTE TITANO, situated in the republic of San Marino, rises about 2100 feet above the level of the sea, and consists throughout of Middle Tertiary deposits, nearly corresponding to the deposits of Dego, Carcare, and Belforte, or to the Bormidian system of Sismonda. These deposits rest upon the "Argille scagliose" of the Apennines; they are overlain by conglomerates, and these in turn by fine sands and marls representing the Tertiary deposits of Sogliano (Tortonian).

In Monte Titano itself the following groups of beds may be distinguished, proceeding from below upwards.

1. Solid coral-conglomerates, consisting of *Porites ramosus,* more than 340 feet thick, with remains of large Gasteropods, Bryozoa, Echinoderms, and large heavy Pectens, some of which show a remarkable resemblance to species found in the Vienna Basin (*Pecten latissimus, Holgeri, aduncus,* &c.). A small Nummulite (*N. planulatus*) also occurs here.

2. Sandy beds, consisting of comminuted remains of Bryozoa, Echinida, and *Porites ramosus,* with numerous Pectens.

3. Marly beds, with *Porites, Pecten,* and *Terebratula,* and with numerous Echinida and Bryozoa.

These beds are regarded by the author as belonging to the Lower Miocene and Upper Eocene.

In all about 70 fossils have been detected in these beds; but a great part of them can only be approximately determined, owing to their defective state of preservation. The species cited are as follows:—

Fishes. *Sphærodus cinctus, Carcharodon megalodon, Oxyrrhina isocetica, O. Desorii, Lamna contortidens, L. cuspidata, Lamna,* sp.

Gasteropoda. *Natica,* sp.?, *Rissoina,* sp., *Conus,* sp., *Cassis,* sp., *Fusus episomus.*

Conchifera. *Pecten Haueri, P. Michelotti, P. miocenicus, P. deletus, Pecten,* sp., *Janira,* sp., *Lima,* sp., *Spondylus,* sp.

Brachiopoda. *Terebratula bisinuata.*

Bryozoa. *Membranipora,* sp., *Lepralia,* sp., *Retepora vibicata, Eschara undulata, E. subchartacea, Vincularia,* sp., *Discopora,* sp., *Radiopora,* sp., *Hornera,* sp., *H. trabecularis, Myriozoon truncatum.*

Echinodermata. *Rhabdocidaris,* sp., *Cidaris, sp., C. avenionensis, C. calamus, Psammechinus parvus, Clypeaster scutum, Echinanthus scutella?, E. Sopitianus?, E. Wrighti, E. Beggiatoi?, Echinolampas hemisphæricus, E. Laurillardi, E. discus, E. similis, Conoclypus plagiosomus, Echinocyamus Studeri, Periaster Heberti?, P. scarabæus?, Pericosmus latus, P. æqualis?, Linthia cruciata?, Macropneustes Meneghinii, M. brissoides?, M. pulvinatus?, Eupatagus ornatus, Spatangus ocellatus?*

Corals. *Trochocyathus elegans, Stylocœnia,* sp., *Porites ramosus.*

Foraminifer. *Nummulites planulatus.*

As regards the distribution of these fossils in the different strata, the Gasteropods may be said to reach their maximum in the coral-conglomerates, the Pectens in the sandy beds, and the Echinida and Bryozoa in the marly deposits, in which also the fossils are best preserved. There seems to be no difference of age between the strata; and their differences are consequently to be accounted for solely by external conditions. The author comes to the conclusion that the group of deposits of which Monte Titano is composed must have been formed during a period of depression. [W. S. D.]

4. Plants *from the* Devonian *of* Ottendorf *and* Braunau *in* Bohemia. By Dr. Dionys Stur, For.C.G.S.

[Proc. Imp. Geol. Inst. Vienna, January 21, 1873.]

Callipteris conferta, generally well preserved, is not uncommon in the bituminous limestones of Ottendorf. It also occurs occasionally in the form described by Weiss as *C. prælongata*, in which the pinnules at the apex of the pinnæ are elongated, and the pinnæ thus acquire a remarkable fan-like structure, those situated near the apex of the frond forming a far more acute angle with the rhachis than those nearer the base, which finally diverge nearly at right angles. A piece of shale from Braunau contains a plant closely resembling the figure of *Xenopteris* (*Neuropteris*) *Dufresnoyi*, Brong., but differing therefrom in the oval form of its pinnule, which appears constricted at the base, like that of a *Cyclopteris*, and in its much coarser veins, some of which, at least in the upper half of the pinnule, seem to anastomose as in *Sagenopteris*. From the *Cyclopteris*-like pinnules which, according to Weiss, clothe the rhachis of *Odontopteris obtusa*, Brong., those from Braunau differ in their coarser venation and in the smaller constriction of their base. The author is inclined to regard the plant as a new species, analogous to *Xenopteris Dufresnoyi*. [Count M.]

5. Fossil Phyllosomes, *from* Solenhofen. By Prof. K. von Seebach.

[Zeitschr. deutsch. geol. Gesellsch. Bd. xxv. Heft 2.]

Prof. Seebach maintains that the fossil described by Münster under the name of *Phalangites priscus*, and referred by him to the Order Phalangida among the Arachnida, is in reality a Phyllosome. The animal was placed with the true spiders under the name of *Palpipes* by J. R. Roth, who distinguished two species of the genus, *P. priscus* and *P. cursor*. Quenstedt distinguished also a *Pycnogonites uncinatus*. H. von Meyer regarded the forms in question as Crustacea of doubtful position.

From a careful examination of 18 fine specimens, the author is convinced that the forms described under the generic names of *Phalangites*, *Palpipes*, and *Pycnogonites* are fossil Phyllosomes, as, indeed, was indicated by Gerstäcker ten years ago, in a note which seems to have escaped observation. The living Phyllosomes are known to be larval states of the Palinuridæ, a family which includes two described genera from Solenhofen, namely *Palinurina* and *Eryon*; and from the great predominance of the latter, the author is inclined to regard his Phyllosomes as, for the most part, larvæ of species of that genus. [W. S. D.]

6. *New* Istrian Fossils. By Dr. G. Stache.

[Proc. Imp. Geol. Inst. Vienna, April 15, 1873.]

Dr. Stache has communicated some of the results of his geological investigations in Istria to the Geological Institute. He describes:—

1. A dark bituminous calcareous shale, filled with large Forami-

nifera, among which an elongated Spiroliniform *Péneroplis* is particularly abundant. A species nearly allied to *P. planatus*, Ficht. & Moll., occurs more sparingly. Associated with these Foraminifera is a finely striated *Anomia*, most nearly approaching *A. tenuistriata*, Desh. The horizon of the bed in which these fossils occur, near Divaca, is that of the lowest Foraminifera-beds of the Liburnian stage, lying immediately upon the uppermost Rudista-zone. The author remarks on the occurrence of *Peneroplis* so low down in the Eocene series.

2. A pale grey limestone, also very rich in Foraminifera, belonging to the uppermost division of the Rudista-limestones, above the rich Hippurite bed of Valresina. In this a large globular Foraminifer (10–12 mill. in diameter) occurs, and is rendered very conspicuous by the contrast of its white shell with the grey limestone. A section of this form shows nearly the structure of *Orbitulites*. The surface of each layer presents extremely fine convoluted ridges, resembling those described by Carpenter on the exterior of *Parkeria*. The author considers that there are sufficient grounds for forming a new genus for this Foraminifer, in the form and arrangement of the chambers, in which it approaches *Orbitulites*, and in the chemical constitution of the shell, which is entirely calcareous.

3. A thinly laminated calcareous shale in the neighbourhood of Sopra Cossi, near Albona, in Southern Istria, belonging to the Upper Rudista-limestones, but containing Ophiurida and plants resembling those of the lithographic stone of Solenhofen.

4. A deposit in the southernmost part of Istria, from which an Ammonite, nearly approaching *A. cenomanensis*, d'Arch., has been obtained. This seems to indicate the occurrence of Lower Turonian or Upper Cenomanian deposits in Istria. [W. S. D.]

7. Dolomitic Pseudomorphs *of* Garnet. By Dr. G. Laube.

[Proc. Imp. Geol. Inst. Vienna, January 7, 1873.]

The dolomitic veins which traverse the veins of hæmatite in the Red Wall near Orpus, in the Erzgebirge, contain amygdaloid portions, consisting of a nucleus of dolomite and an envelope of hæmatite. The hæmatite envelope is finely fibrous, and encloses a sharp-angled, smooth-faced nucleus of drusy dolomite, the cystalline form being that of garnet. The process of formation was therefore as follows: crystals of garnet were first enveloped by hæmatite, then decomposed and carried off, leaving behind them a regular space, which was afterwards filled with dolomite. [Count M.]

8. Red Antimonio-sulphide *of* Silver. By M. Karl Reytt.

[Proc. Imp. Geol. Inst. Vienna, January 21, 1873.]

This mineral (rhombohedral ruby-blende of Mohs) has lately been found abundantly at Joachimsthal, North Bohemia, accompanying a vein of white calc-spar enclosed in fine-grained mica-schist. Ar-

senic, with innumerable small crystals of the red silver-ore, lie close upon the bands of calc-spar, the quantity of silver contained in the deposit being 5·59 per cent. The middle of the vein is occupied by nickeliferous pyrites, associated with white sulphide of nickel, the latter containing 3 per cent. of silver and 19 per cent. of nickel. The finest crystals of the silver-ore occurred in druse-like cavities between the white calc-spar and the arsenic. They varied in colour from ruby-red to lead-grey. [COUNT M.]

9. REMAINS *of* SIRENIA *found in* VENETIA. By Baron A. DE ZIGNO.

[Proc. Imp. Geol. Inst. Vienna, January 21, 1873.]

IN his 'Zoologia fossile,' published in 1827, Prof. Catullo gave a short catalogue of the collection of the University of Padua, in which he mentioned ribs of *Manatus* from Castel Gomberto. The specimens referred to are two blocks of coarse limestone, containing 14 ribs, which have all the characters of those of *Halitherium*. The author has found fragments of similar ribs in the Miocene strata of Treviso. The most important remains of these Sirenia have been found lately in the provinces of Verona and Belluno. The bones obtained on the Monte Zuello, near Montecchio, in the Veronese, are the oldest, and were imbedded, with fragments of the carapace of a turtle and teeth and vertebræ of a crocodile, in a limestone which belongs to the lower part of the zone of *Serpula spirulœa*. They consist of a skull, wanting the lower jaw, 31 ribs, 27 vertebræ, and several undeterminable fragments.

The glauconitic limestone of the basin of Belluno, in which remains of *Halitherium* are found, was formerly regarded as Eocene, from its lying beneath the grey Miocene Molasse, and containing remains of crocodiles and teeth of *Carcharodon*, *Pachyodon*, and *Rhinoceros*; but the Miocene fossils found in it by M. Taramelli show that it forms one whole with the Molasse which overlies it, and must also be regarded as Miocene. The bones found at Cavarzona, in this district, include two fragments of lower jaws, an intermaxillary bone, fragments of the zygomatic arch and of several ribs, and five vertebræ. The species found in the two localities are distinct; that of Montecchio proves the existence of *Halitherium* in Eocene times.

[COUNT M.]

10. *The* RIGI *and the* MOLASSE-DISTRICT *of* CENTRAL SWITZERLAND. By M. F. J. KAUFMANN.

[Proc. Imp. Geol. Inst. Vienna, March 4, 1873.]

M. KAUFMANN'S volume of the 'Beiträge zur geologischen Karte der Schweiz' relating to this district is to be regarded as a continuation of his work upon the geology of Mont Pilate.

In the district of the Rigi also the *Caprotina*-limestone proves to be a facies of the upper part of the Lower Cretaceous formation,

not confined to any definite horizon. It both overlies and underlies the Aptian Orbitulite-beds, without any difference in its petrological or palæontological characters.

The Eocene formations are as follows, in ascending order:—

1. Pilatus-beds (*Pilatan*), 660 feet thick, divided into
   a. Complanata-beds, consisting of limestones and green sandstones, with peculiar faunas which mutually exclude each other; and
   b. Pectinite-shales.

2. Rigi-beds (*Rigian*, Lower Flysch), 2660 feet thick, with local intercalations of conglomerates and limestones (Lowerz limestones), and with a rather rich fauna and flora, varying according to the nature of the rock.

3. Obwaldner-beds (*Silvan*, Upper Flysch), 2660 feet thick, consisting of more compact rock, but poor in fossils.

The author's investigations of the Molasse have led him to results differing somewhat from those generally accepted, as will be seen from the following Table:—

<table>
<tr><th>Divisions.</th><th colspan="3">Marine Molasse.</th><th colspan="3">Freshwater Molasse.</th></tr>
<tr><td rowspan="2">Upper Molasse, 300–600 metres.</td><td rowspan="2">Upper Marine Molasse.</td><td>Berne beds.</td><td>Aargau beds.</td><td rowspan="2">Upper Freshwater Molasse.</td><td rowspan="2">Napf beds.</td><td rowspan="2">Allis beds.</td></tr>
<tr><td colspan="2">St. Galle beds.</td></tr>
<tr><td>Middle Molasse, 300–600 metres.</td><td>Middle Marine Molasse.</td><td colspan="2">Lucerne beds.</td><td>Middle Freshwater Molasse.</td><td>Hohe Rhonen beds.</td><td>Aarwang beds.</td></tr>
<tr><td>Lower Molasse, 400–500 metres.</td><td>Lower Marine Molasse.</td><td colspan="2">Horwer beds.</td><td>Lower Freshwater Molasse.</td><td colspan="2">Red Molasse.</td></tr>
</table>

[Count M.]

11. *The* Cephalopoda *of the* Zlambach *and* Hallstatt Beds. By Dr. E. von Mojsisovics.

[Proc. Imp. Geol. Inst. Vienna, June 17, 1873.]

Dr. von Mojsisovics has published, as the first number of the sixth volume of the 'Abhandlungen' of the Imperial Geological Institute of Austria, the first part of his geological investigation of the neighbourhood of Hallstatt, in which he describes the remains of Cephalopoda obtained from the Zlambach and Hallstatt beds. These are numerous, and belong to the following genera:—*Orthoceras* (9 sp.), *Nautilus* (38 sp.), *Lytoceras* (14 sp.), *Phylloceras* (6 sp.), *Pinacoceras*, g. n. (32 sp.), *Sageceras*, g. n. (1 sp.), and *Arcestes* (16 sp. belonging to the group of *A. tornatus*).

With regard to *Orthoceras*, the latest representatives of which occur in the Upper Trias, the author states that in all the species with a *long* body-chamber the occurrence of the peculiar impressions of the adherent surface of the mantle (*stries creuses* of Barrande), first observed by the brothers Sandberger, was ascertained; and in a species with a short body-chamber, distant septa, and narrow siphuncle, the occurrence of a periodical truncation associated with a formation of terminal caps seemed to be very probable.

In his treatment of the Ammonites the author adopts the classification inaugurated by Suess, and carried out for the Jurassic Ammonites by Waagen and Zittel, regarding the course adopted by these authors as the only one likely to lead to a natural (or genealogical) view of this group of fossils. He indicates repeatedly, especially in connexion with the genera *Lytoceras*, *Pinacoceras*, *Sageceras*, and *Arcestes*, that he can by no means arrange the Goniatites as a distinct generic series in opposition to the Ammonites, in accordance with the views of L. von Buch, Beyrich, and Giebel. The Triassic representatives of the above-mentioned genera are most closely related in all essential peculiarities of organization and habit to Goniatitic predecessors; the Ammonites from the Permian sandstone of Artinsk, Waagen's Permian Ammonite from the Salt range of the Punjàb, and certain Triassic forms partially bridge over the gap which still exists between the older Goniatites and the Ammonites of the Trias. By far the greater part of the genera of Ammonites occurring in the Alpine Trias have their roots in the Palæozoic Goniatites; and some of them may apparently even be traced back into the Upper Silurian formations. The greater part of these Palæozoic genera become extinct in the Upper Trias, when they attain the height of their development, but at the same time show signs of senile degradation, analogous to the phenomena observed during the gradual extinction of the later Ammonitic types in the Cretaceous period.

The character of the Ammonite-fauna of the upper Alpine Trias is preponderantly Palæozoic, in striking contrast to that of the beds with *Arcestes Studeri*, in which *Ægoceras* and *Amaltheus*, which are wanting in the faunas of Hallstatt and St. Cassian, have already made their appearance. Of the later genera only *Phylloceras* and *Lytoceras* are represented by a few forms.

A remarkable fact, difficult of explanation in the present state of the theory of descendence, is the variation in the same direction which occurs nearly simultaneously in the different genera of Ammonites—namely, the complication of the sutures, and the turning forward of the striæ of growth upon the convex part, by which the Goniatitic stage of development is converted into the Ammonitic stage. In the transition stages *ceratitiform* and *heterophylliform* sutures occur. The Triassic species of *Lytoceras* are all in this condition, presenting heterophylliform (monophyllous) sutures. But examples are not wanting of forms which have remained upon a lower Goniatitic grade, such as *Sageceras* and the group of *Arcestes delphinocephalus*, which persists, as a Devonian antiquity, up to the St.-Cassian beds.

The new genus *Pinacoceras*, established for *Ammonites Metternichi* and some allied forms, is characterized as follows:—Animal unknown; shell very narrow, with a high mouth, smooth, often having folds and tubercles; body-chamber occupying $\frac{1}{2}$–$\frac{2}{3}$ of the last whorl, with short lobes projecting from the convex part; muscular impression commencing on the convex part at the anterior extremity of the body-chamber near the aperture, and descending upon the lateral parts to the concave part at the hinder extremity of the body-chamber; surface of attachment of the mantle consisting of punctiform or striiform elevations; wrinkled layer of separated radiating striæ projecting as a lobe beyond the margin of the aperture upon the convex part of the preceding whorl; embryonic nucleus vesicular; lobes consisting of three different groups:—a variable number of adventitious lobes formed by the removal of the siphonal tubercles, and increasing by division; three deep main lobes; and a variable number of auxiliary lobes.

The new genus *Sageceras*, founded for *Ammonites Haidingeri* and its allies, approaches *Pinacoceras* by its flat, discoidal form, and the great number of lobes lying outside the line of projection of the preceding whorl. An essential distinction is furnished, however, by the process of the concave part, which is distinctly marked by the direction of the striæ of growth. There are further differences in the peculiar form of the lobes and in the different nature of the wrinkled layer, which is granular in *Sageceras* as in *Nautilus*.

In *Arcestes* the varices prove to be really remnants of former apertural margins, and must not be confounded with the muscular impressions which frequently occur in *Pinacoceras*. These internal ridges of the shell occur close behind the margin of the aperture in those forms of *Arcestes* in which the shell is not inverted at the margin. There is consequently only a morphological difference between varices and contractions, the latter being produced by the inversion of the shell at the margin of the aperture.

It is a remarkable fact that of all the fossils of the Noric division of the Hallstatt limestone and of the Zlambach beds, not a single species has hitherto been found beyond the region of the north-eastern Alps (Salzburg, Upper and Lower Austria, and Styria).

[W. S. D.]

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

VOLUME THE TWENTY-NINTH.

1873.

PART II. MISCELLANEOUS.

CONTENTS OF PART II.

Alphabetically arranged—the Names of the Authors in capital letters.

ALPHABETICAL INDEX

TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described, and those of which the names are printed in italics are also figured.]

THE END.

Printed by TAYLOR AND FRANCIS, Red Lion Court, Fleet Street.